Cooling Load Estimation for a Multi-story office building

A

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

Master of Technology

In

Mechanical Engineering

(Specialization: Thermal Engineering)

By

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CERTIFICATE

*This is to certify that the thesis entitled, "**Cooling Load Estimation for a Multi - story office building**" submitted by **Mr. Sandip Kumar Sahu** in partial fulfillment of the requirements for the award of Master of Technology in Mechanical Engineering with Thermal Engineering specialization during session 2013-2014 in the Department of Mechanical Engineering, National Institute of Technology, Rourkela.*

It is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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Place: Rourkela

ACKNOWLEDGEMENT

First and foremost I record my sincere gratitude and respect towards my project supervisor, **Dr. S. MURUGAN**, Associate professor, Department of Mechanical Engineering, for his valuable guidance, valuable suggestions and endless support during my study. He has not only been a wonderful supervisor, but also a genuine person. I consider myself extremely lucky to be able to work under guidance of such a dynamic personality. This thesis was made possible by his patience and persistence.

I also express my sincere thanks to **Prof. K.P. MAITY, HOD, Department of Mechanical Engineering, Prof. R.K. SAHOO, Professor and Group head, Thermal Engineering Specialization, Mr. PARTHA SARATHI SET, Manager-Construction Air-conditioning Project Division, Blue Star India (P) Ltd.** and also the other staff members of Department of Mechanical Engineering, NIT Rourkela, for providing me the necessary facilities for my work.

I also express my special thanks to our research scholar **Mr. Abhishek Sharma** and **Mr. Arun Kumar Wamankar** for his valuable suggestion and my batch mates **Mr. Chuneshwar Lal Verma** and **Pawan Tiwari** for their help during the research work.

I would like to thanks my parents for their unconditional support, love and affection. Their encouragement and never ending kindness made everything easier to achieve.

DATE-　　　　　　　　　　　　　　　　　　　　　SANDIP KUMAR SAHU

ABSTRACT

Human comfortness is essential now a day because of the improvement in life style and increasing atmospheric temperature. Electrical air conditioning machines are not most suitable for large buildings because of the higher power consumption and shorter life. Central air conditioning is more reliable for easy operation with a lower maintenance cost. With large buildings such as commercial complex, auditorium, office buildings are provided with central air conditioning system. Educational and research institutions also need human comfortness, as the population of student community increase year by year. The effective design of central air conditioning can provide lower power consumption, capital cost and improve aesthetics of a building. *This paper establishes the results of cooling load calculation of different climate conditions by using CLTD method for a multi-story building which is a part of an institute.* Cooling load items such as, people heat gain, lighting heat gain, infiltration and ventilation heat gain can easily be putted to the MS-Excel programme. The programme can also be used to calculate cooling load due to walls and roofs.

And results were compared with the standard data given by ASHRAE and CARRIER Fundamental Hand Books, and results are satisfactory. It is also seen that in this paper cooling requirement of summer is about 9 % more as compare to monsoon for climate condition of Rourkela.

Keywords:- CLTD, Cooling Load, Air conditioning, Human comfortness.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1. General

In present days the environmental problem is one of the most serious problems. Energy consumption by industries and buildings are responsible for this problem. About 72% of world energy is consumed by infrastructure, industry, commercial buildings, residential houses, and markets. In a large building or complex, which is air-conditioned, about 60% of the total energy requirement in the building is allocated for the air-conditioning plant installed to use the cooling purpose.

Exact prediction of the cooling and heating load, proper sizing of the heat ventilation air-conditioning (HVAC) system and optimal control of the HVAC systems are important to minimize energy consumption. Root factors that affect cooling loads are the external climates such as outdoor temperature, solar radiation and humidity. Local climatic conditions are important parameters for the energy efficiency of buildings. Because the energy consumption in buildings depends on the climatic conditions and the performance of heating ventilating and air conditioning (HVAC) systems changes with them as well, better design in building HVAC applications that take account of the right climatic conditions will result in better comfort and more energy efficient buildings.

Calculation of thermal load of building is very essential to find exact air-conditioning equipment and air handling unit, to achieve comfort operation and good air distribution in the air-conditioned zone.

This project ***Cooling load estimation for a multi-story office building*** presents by using CLTD method

1.2. Terminology

Commonly used terms relative to cooling load calculation and heat transfer of the buildings according to the ASHRAE reference are given below.

a) **Refrigeration: -** the term ‘Refrigeration’ means process of removing heat from a substance or space under the controlled conditions. It also include the process of reducing and maintaining the temperature of a body below the surrounding temperature

b) **Unit of refrigeration: -** the practical unit of refrigeration is expressed in terms of ‘tonne of refrigeration (TR)’. A tonne of refrigeration is defined as the amount of refrigeration effects produced by the melting of 1 ton of ice from and at 0 ^{o}C in 24 hours.

c) **Coefficient of performance (COP): -** the COP is defined as the ratio of heat extracted in the refrigerator to the work done on the refrigerant.

d) **Refrigerant: -** refrigerant is the fluid used for heat transfer in a refrigerating system that release heat during condensation at a region of higher temperature and pressure, and absorbs heat during evaporation at low temperature and pressure region.

e) **Air conditioning: -** controlling and maintaining environmental parameters such as temperature, humidity, cleanliness, air movement, sound level, pressure difference between condition space and surrounding within prescribed limit.

f) **CLTD: -** cooling load temperature difference is an equivalent temperature difference used for calculating the instantaneous external cooling load across the walls and roofs.

g) **Humidity: -** it is the mass of water vapour present in 1 kg of dry air, and is generally expressed in terms of gram per kg of dry air (g/kg of dry air). It is also called specific humidity or humidity ratio.

h) **Relative humidity (RH): -** it is a ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure.

i) **Dry bulb temperature (DBT): -** it is the temperature of air recorded by thermometer, when it is not affected by the moisture present in the air. The dry bulb temperature is generally denoted by t_d or t_{db}.

- **j) Wet bulb temperature (WBT): -** it is the temperature of air recorded by a thermometer, when its bulb is surrounded by a wet cloth exposed to the air. The wet bulb temperature is generally denoted by t_w or t_{wb}.
- **k) Dew point temperature (DPT): -** it is the temperature of the air recorded by the thermometer, when the moisture present it beings to condense.
- **l) Heat transfer coefficient: -** it is the rate of heat transfer through a unit area of building envelope material, including its boundary films, per unit temperature difference between the outside and inside air.
- **m) Thermal resistance: -** it is the reciprocal of the heat transfer coefficient and is expressed in m^2-K/W.
- **n) Sensible heat gain: -** direct addition of heat to the enclosed space, without any change in its specific humidity, is known as sensible heat gain.
- **o) Latent heat gain: -** heat gain of space through addition of moisture, without change in its dry bulb temperature, is known as latent heat gain.
- **p) Space heat gain: -** it is the rate of heat gain, at which heat inter into and generated within the conditioned space.
- **q) Space cooling load: -** it is the rate at which energy must be removed from a space to maintain a desired air temperature of space.

1.3 Objective

The objective of this paper is to calculate cooling load to find exact air-conditioning equipment and air handling unit, to achieve comfort operation and good air distribution in the air-conditioned zone.

1.3.1 HVAC system design

The main objectives of HVAC system design are as follows

i. Control of temperature, humidity, air purity and correct pressurization to avoid contamination.

ii. Provide comfort and healthy indoor environment of office buildings, educational buildings, cinemas, libraries, auditoriums, multiplex, shopping centers, hotel, public place,

iii. Provide special air filtration to remove bacteria, high indoor quality, avoid cross contamination.

1.3.2 Cooling load calculation

The objectives of cooling load calculation are as follows

i. To determine be the optimum rate at which heat needs to be removed from space to establish thermal equilibrium & maintain a pre-determined inside conditions
ii. To calculate peak design loads (cooling/heating).
iii. To estimate capacity or size of plant/equipment.
iv. To provide info for HVAC designs e.g. load profiles.
v. To form the basis for building energy analysis

1.4. Human comfort

Human comfort is the condition of mind, which expresses satisfaction with the thermal environment. Air conditioning of any building mainly concerns the comfort of people.

1.4.1. Heat exchange of human body with environment

A human body feels comfortable thermodynamically when the heat produced by the metabolism of human body is equal to the sum of the heat dissipated to the surrounding and the heat stored in the human body by raising the temperature of body tissues.

The phenomena of heat loss from the body can be expressed by Eqn. 1.1.

$$Q_M - W = Q_E \pm Q_S \pm Q_R \pm Q_C \qquad \text{……………. (1.1)}$$

Where

Q_M = metabolic heat produced within the body.

W = useful rate of working.

Q_S = heat stored in the body.

Q_E = heat loss by evaporation.

Q_R = heat loss and gain by radiation.

Q_C = heat loss and gain by conduction and convection.

- The metabolic heat production depends upon the food consumption in the body.

1.4.1.1 Convection heat loss

The convective heat loss from the body is given by the Eqn. 1.2.

$$Q_C = UA\,(T_b\text{-}T_s) \qquad \text{…………….. (1.2)}$$

Where

U = heat transfer coefficient on body surface.

A = body surface area.

T_b, T_s = temperature of the body and surrounding respectively.

The heat will be gained by the body if the temperature of the surrounding is greater than the body temperature and this will increase with increase in U which is function of air velocity. Higher velocities impart more uncomfort when surrounding temperature is higher than body temperature.

1.4.1.2 Radiation heat loss

The radiation heat loss from body to the surrounding is given by the Eqn. 1.3.

$$Q_R = \sigma\,(T_b^4\text{-}T_s^4) \qquad \text{…………….. (1.3)}$$

Where

σ is Stefan-Boltzmann constant.

Body gains the heat from surroundings when $T_s>T_b$ and loses heat to the surrounding when $T_s<T_b$

1.4.1.3 Evaporation heat loss

The heat loss by evaporation is given by the Eqn 1.4

$$Q_E = C_dA\,(Ps\text{-}Pv)\,hfg.C_c \qquad \text{………….. (1.4)}$$

Where

C_d = diffusion coefficient in kg of water evaporated per unit surface area and pressure difference per hour.

P_s =saturated vapour pressure corresponding to skin temperature.

P_v = vapour pressure of surrounding air.

h_{fg} =latent heat of vaporization = 2450 kj/kg.

C_c = factor which account s for type of clothing worn

1.5 Effective temperature

The degree of warmth or cold felt by a human body depends mainly on the following three factors

1. Dry bulb temperature, 2. Relative humidity and 3. Air velocity.

In order to evaluate the combined effects of the three factors is called effective temperature, It is defined as that index which correlate the combined effects of air temperature, relative humidity and air velocity on the human body.

The practical application of the concept of effective temperature is presented by the 'comfort chart' as shown in Fig 1.1. This chart is the result of research made in different kinds of people subjected to wide range of environmental temperature, relative humidity and air movement by the ASHRAE.

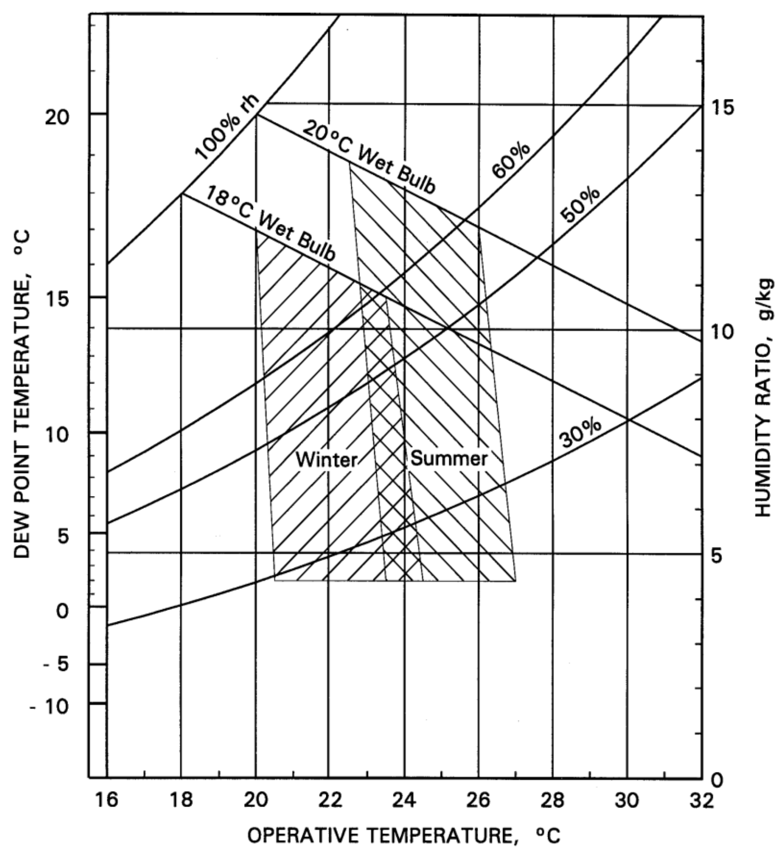


Fig 1.1 comfort chart

All men and women above 40 years of age prefer 0.5 ^oC higher effective temperature than the person below 40 years of the age.

1.5.1 Factor governing optimum effective temperature

The optimum effective temperature is affected by the following important factors.

a) **Climatic and seasonal difference:-** it is known fact that people living in colder climates feel comfortable at a lower effective temperature than those living in warmer regions. There is a relationship between the optimum indoor effective temperature and the optimum outdoor temperature, which change with seasons. It can be see from comfort chart that in winter, the optimum effective temperature is 19 ^oC where in summer this temperature is 22 ^oC.

b) **Clothing:-**it is another important factor which affects the optimum effective temperature. It may be noted that the person with light clothings need less optimum temperature than person with heavy clothings.

c) **Age and sex:-**we have already discussed that the women of all ages required higher effective temperature (about 0.5 ^oC) than men. Similar is the case of old and young people. The children also need higher effective temperature than adult.

d) **Activity:-**when the activity of the person is heavy such as people working on the factory, dancing hall, then low effective temperature is needed than for the people sitting in cinema hall or auditorium.

e) **Latitude:** - the effective temperature is increases by about 0.5℃. with every 5^o reduction in latitude.

CHAPTER 2

LITERATURE REVIWE

Andersson et al. [1] designed heating and cooling loads for a sample residential building at different orientations, using a development version of the building energy analysis computer program BLAST. They identified that the total loads were found to be higher for north than south orientation except in extreme southern latitudes of the U.S.

Omar et al. [2] calculated the hourly cooling load due to different kinds of wall, roof and fenestration using transfer function method (TFM). The output of this method was compared with the well-known Carrier program and the results were acceptable. In the case of cooling load, when the results were compared with the ASHRAE examples, some differences were noticed due to wall and roof. They also studied the effects of changing the wall color on cooling load.

Adnan Shariah et al. [3] studied the effect of the absorptance of external surfaces of buildings on heating, cooling and total loads using the TRNSYS simulation program. Two types of construction materials, namely heavy weight concrete block and light weight concrete were used in the simulation. They also calculated the effects of the absorptance on energy loads for insulated buildings. They reported that, for uninsulated buildings, as the absorptance was changed from one to zero, the total energy load decreased by 32%, while for insulated buildings, it decreased by 26% in Amman. Whereas the decrease was about 47% for uninsulated and 32% for insulated buildings in Aqaba.

Kulkarni et al. [4] optimized cooling load for a lecture theatre in a composite climate in India. The lecture theatre had a dimension of 16m×8.4m×3.6m and was situated at Roorkee (28.58^{o}N, 77.20^{o}E) in the northern region of India. The monthly, annual cooling load and cooling capacity of air conditioning system was determined by a computer simulation program. They reported that the use of false celling, ceramic tiles on roof and floor, electro chromic reflective colored, 13mm air gap, clear glass gave the best possible retrofitting option.

Suziyana et al. [5] analyzed the heat gain and calculated cooling load of a Computer Laboratory and Excellent Centre Rooms in the Faculty of Mechanical Engineering, University Malaysia Pahang by using cooling load calculation method and cooling load factor method based on

ASHRAE 1997 fundamental handbook and then verified by data provided by contractor of building. From this calculation, it was found that the highest heat gain in the Computer Laboratory Room and in Excellent Centre Room is 20458.6 W and 33541.3 W respectively.

Hani H. Sait [6] estimated the thermal load for the engineering building located in Rabigh and compared the results by the outcomes from a HAP 4.2 program. It was reported that, there was a little difference among the two results due to defining the thermal resistance for the used materials of the wall, roof, and windows.

Yan Suqian et al [7] cooling load coefficient method and steady calculation method were used to estimate and compare cooling load of spinning workshop. They concluded that the results of two algorithms were little different and steady calculation method was more simple and efficient.

A. Fouda et al [8] predicted a modified method of calculating the cooling load for residential buildings. The outcome of this method were compared with the ASHRAE standards and they found that the results come from this method were more accurate and effective.

Lin Duanmu et al [9] predicted the hourly building cooling load for urban energy planning by using Hourly Cooling Load Factor Method (HCLFM) that can provide fast and fair estimate of building cooling load for a large-scale urban energy planning. This method was applied to an office building in Beijing, China. The calculated results showed that the dynamical trend of the cooling load was reasonable.

Christian et al. [10] the formulation of a new clear-sky solar radiation model suitable for algorithms calculating cooling loads in buildings were established. The main motive of formulating this model was to replace the ASHRAE clear sky model of 1967 to overcome the limitation of this model. The new model was derived in two steps. The first step consisted of finding a reference irradiance dataset from the REST2 model and the second step consisted of fits derived from a REST2-based reference irradiance dataset. The resulting models and its tabulated data were expected to be integrated in the 2009 ASHRAE Handbook of Fundamentals.

Abdullatif et al. [11] designed general regression numeral networks (GRNN) and investigated to optimize HVAC thermal energy storage in residential buildings as well as office buildings. The simulation software ESP-r was used to calculate hourly cooling loads for three office buildings using climate conditions in Kuwait. The cooling load data for 1997–2000 was used for simulating and testing the neural networks (NN). The results showed that a properly designed NN is a powerful tool for optimizing thermal energy storage in buildings based only on external temperature records.

Fernando Simon et al. [12] evaluated the thermal loads of non-residential buildings based on simplified weather data, using the Transfer Function Method to run load calculations and the validation was evaluated according to the ASHRAE Standard 140. They also reported that the methodology showed good results for cases with low mass envelope, but revealed limitation to represent thermal inertia influence on the annual cooling and heating loads.

Mehmet Azmi et al. [**13**] investigated the effects of different outdoor design conditions on cooling loads and air conditioning systems. The cooling coil capacities obtained from the different outdoor design conditions considered in this studies were compared with each other. It was reported that a significant part of the cooling load dependent on outdoor weather conditions.

Tingyao Chen et al. [14] developed the statistical method for the normal selection of sequences of coincident design weather parameters in order to properly determine peak cooling loads. Radiant time series (RTS) was used to derive overall periodic transfer factors responding to different periodic weather heat sources. Results show that horizontal solar irradiance calculated with the method suggested by ASHRAE was always higher in the range of 4–20%, than the measured value in different months. The peak cooling load resulted from the old design weather data was always higher in the range of 12–50%, than the results from the new design weather data.

Naouel Daouas [15] studied on optimum insulation thickness in walls and energy savings in Tunisian buildings using analytical method based on Complex Finite Fourier Transform (CFFT) for calculation of cooling and heating transmission loads considering different types of wall colors and wall orientations. It was assumed that wall orientation had a small effect for optimum insulation thickness, but more topical effect on energy savings which reached a maximum value of 23.78 TND/m^2 for east facing wall. Their analysis showed that economic parameters, like insulation cost, inflation and discount rates, energy cost and building life, had a perceptible effect on optimum insulation and energy saving. They also performed a comparison of the present study with the degree-days model.

Wong et al. [16] studied the development of a new example weather year and generated the mathematical model to design occupants load profiles using Monte Carlo simulation method for subtropical climate. For determining the HVAC energy consumption in buildings this method and results were very useful.

Francesco Causone [17] investigated and designed radiant cooling load systems for removal of solar heat gain. They used heat balance method and time series method to calculate the cooling load and proposed a simplified procedure to calculate the magnitude of the solar heat load.

Fernando et al [18] proposed a new approach based on a stochastic simulation method for uncertainty in peak cooling load calculations. The stochastic solution was compared with the conventional solutions, and a universal sensitivity analysis was assumed to identify the most significant uncertainties.

Christian Ghiaus et al [19] reported that the calculation of optimal thermal loads of intermittently heated buildings. An unconstrained optimal control algorithm was proposed which used feed-forward to compensate the weather conditions and model predictive programming (MPP) for set-point tracking. They concluded that the peak load depended on the set-back time of the indoor temperature. The peak load was larger while energy consumption and the set-back time were smaller.

Meral Ozel [20] utilized a computer program which was developed in Matlab to determine optimum insulation thickness according to cooling requirements of buildings in a hot climate. The investigation was carried out under steady periodic conditions for different wall orientations during the summer period using an implicit finite difference method. It was seen that for cooling season, the most economical orientation was north with an optimum insulation thickness of 3.1 cm. Highest thickness was obtained for the east and west walls, while the lowest value of optimum insulation thickness was obtained for the north-facing wall

Stefano et al [21] the development of a simplified calculation method for design cooling loads in underfloor air distribution (UFAD) systems was described. They compared the results obtained from a UFAD system with traditional mixing overhead (OH) systems. The results revealed that, generally, underfloor air distribution (UFAD) system had a peak cooling load 19% higher than an overhead (OH) cooling load.

Mridul Sarkar [22] investigated a simple equipment load formulations for the two modes namely Blow-through (BT) and draw-through (DT) modes. It was proved that DT type AHU showed higher cooling load than BT type in the case of derived loads for a cooling-dehumidifying chilled water coil.

Feng et al [23] investigated the difference of cooling load between radiant and air systems. The results shows that the total cooling energy of radiant systems can be 5 to 15% higher than air systems at the zone level 24-h, for zones without solar load peak cooling rate at the radiant cooled surface can be 7 to 35% higher than air system.

Jenkins et al [24] applied an emulation tool for probabilistic future cooling loads for mechanically cooled offices. The model of future building failure, were applied to a mechanically cooled building, was discussed and the use of the tool in such a condition was summarized.

Yang et al [25] investigated the heat transfer through a photovoltaic (PV) wall to determine the cooling load component added by building-integrated PV walls. They found that when using the average outdoor temperature and recommended film coefficients of the special building cooling load component can be obtained properly.

CHAPTER 3

DATA COLLECTION AND METHODOLOGY

3.1 Basic Information

Before estimating cooling load of any building there are some basic informations are necessary to design an exact HVAC systems, like building orientation, weather condition, building spacing, buildings materials etc. The more exact the information the more accurate will be the load estimated.

3.1.1 Building Location

The multi-story building considered in this study is situated in Rourkela and located at 84.54E longitude and 22.12N latitude in Sundergarh district of Odisha, India at an elevation of about 219 meters above mean sea level.

3.1.2 Climate condition

Rourkela has a tropical climate. During Southwest monsoon (June – September), it receives high rainfall and retreats Northeast monsoon (December – January). Average annual rainfall ranges between 160 and 200 cm. The minimum and maximum temperatures ranges are 7℃ to 47℃ with a mean minimum and maximum temperature range of 9.8℃ to 39.2℃ during coldest and hottest months. Table 3.1 gives the average high and low temperature of Rourkela.

Table 3.1 Average high and low temperature (in ^{o}C) of Rourkela according to months

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Average high	24	27	31	37	38	33	30	29	29	29	27	24	29.7
Average low	9	13	17	21	23	23	23	22	22	19	14	10	18

Table 3.2 Average relative humidity according to months

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Average RH %	54	50	40	36	46	70	84	86	83	73	63	59	62

3.1.3. Building Structures

The dimension of the building which is to be air conditioned is, 104×61×48m in size. It has four floors included the ground floor. The exterior walls of building consists of 230 mm common bricks + air space + 230 mm common bricks with 13 mm cement mortar and 26 mm (13 mm both side) sand cement plaster. The interior walls of building are consist of 230 mm common bricks with 26 (13 mm both side) inch sand cement plaster. The roofs consist of 152 mm concrete poured in a metal sheet with 13 mm plaster. The windows consist of single glass materials of 12.7mm thick with frame panel.

3.2 Load Components

The total heat required to be removed from the space in order to bring it at the desired temperature (21-25℃) and relative humidity (50%) by the air conditioning equipment is known as cooling load or conditioned load. This load consists of external and internal loads.

3.2.1 External and Internal heat gains

External heat gains arrive from the transferred thermal energy from outside hot medium to the inside of the room. The heat transfer takes place from conduction through external walls, top roof and bottom ground, solar radiation through windows and doors, ventilation and infiltration. Other sources are internal heat gain like people, electric equipment and light. Fig 3.1 illustrates the load components.

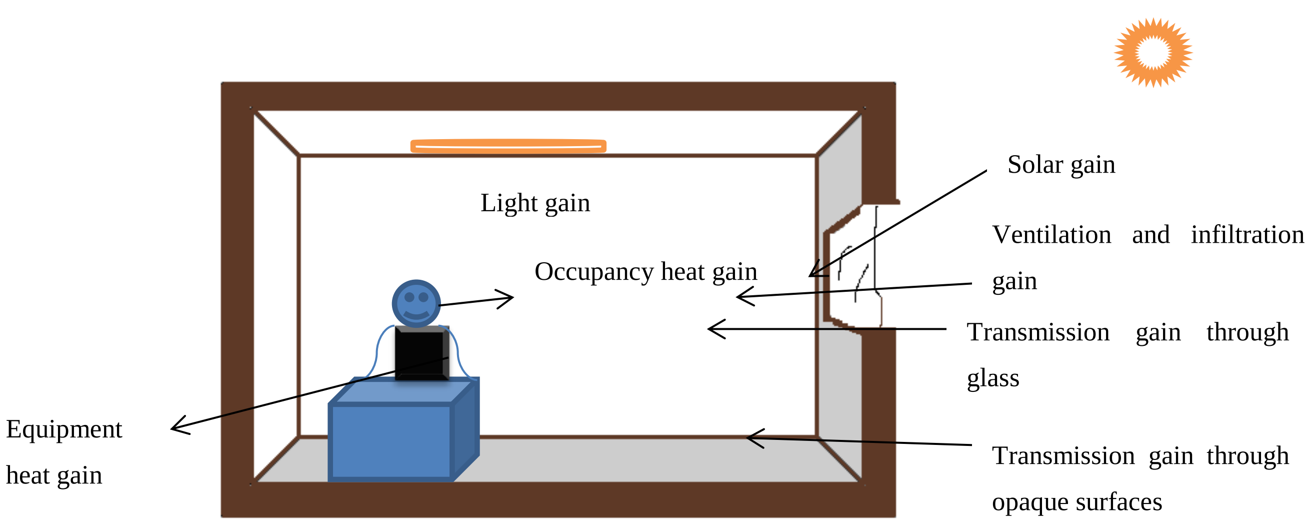


Fig 3.1 *Load components*

3.2.1.1 Sensible Heat Gain through Opaque Surface

The heat gain through a building structure such as walls, floors, ceiling, doors and windows constitute the major portion of sensible heat load. The temperature difference across opaque surfaces causes heat transfer through these surfaces.

As shown in Fig. 3.2, heat from outside air is transferred mainly by convection to outer surface. The heat is then transferred by conduction through the structure to inside surface. The heat from inside surface is transferred by convection to the room air.

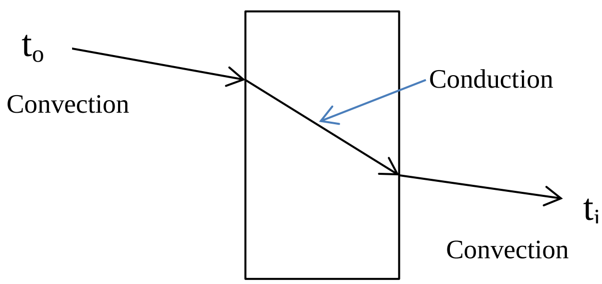


Fig 3.2 *Heat transfer through opaque surface*

The rate of heat transfer from outside air to inside air is calculated by the formula.

$$Q = UA(CLTD)_{corr} \qquad \text{……………..} \ (3.1)$$

Where U = over all heat transfer coefficient (W/m^2-^{o}C)

CLTD = cooling load temperature difference (^{o}C)

A = surface area (m^2)

3.2.1.1.1 Overall heat transfer coefficient

When the wall, floor, or ceiling is made up of layer of different materials as shown in Fig 3.3, then the overall heat transfer coefficient 'U' can be calculated by the formula

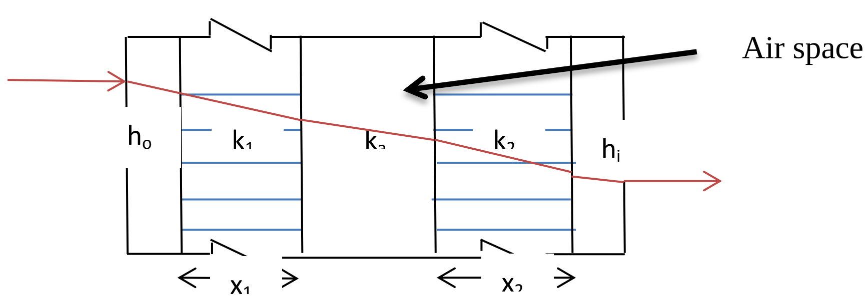


Fig 3.3 *Heat transfer through a composite wall with air space*

$$U = \frac{1}{\frac{1}{h_o} + \frac{x_1}{k_1} + \frac{1}{k_a} + \frac{x_2}{k_2} \ldots\ldots \frac{1}{h_i}} \qquad \ldots\ldots\ldots\ldots\ldots (3.2)$$

Commonly the building walls may consist of non-homogeneous materials for example hollow bricks, air gap and plaster. Heat transfer through these types of wall is quite complicated as it involves simultaneous heat transfer by conduction, convection and radiation as shown on Fig 3.3. All material has different kinds of thermo-physical properties; the thermo-physical properties of common building materials have been measured and presented in ASHRAE and other handbooks. Table 3.3 lists out thermo-physical properties of commonly used building materials.

Table 3.3 Thermo-physical properties of some common building and insulating materials

Material	**Description**	**Density**	**Specific heat**	**Thermal conductivity**	**Conductance**
		kg/m^3	kJ/kg.K	W/m.K	W/m^2.K
Bricks	Common	1600	0.84	0.77	-
	Face	2000	0.84	1.32	-
Masonry materials	Concrete	1920	0.88	1.73	-
	Plaster cement	1885	0.796	8.65	-
	Hollow clay tiles				
	10 cm	-	-	-	5.23
	20 cm	-	-	-	3.14
	30 cm	-	-	-	2.33
	Hollow concrete block				
	10 cm	-	-	-	8.14
	20 cm	-	-	-	5.23
	30 cm	-	-	-	4.54
Wood	Ply	544	-	0.1	-
	Hard	720	2.39	0.158	-
	Soft	512	2.72	0.1	-
Glass	Window	2700	0.84	0.78	-
	Coro silicate	2200	-	1.09	-
Insulating materials	Fiberglass board	64-144	0.7	0.038	-
	Core board	104-128	1.88	0.038	-
	Mineral or glass wool	24-64	0.67	0.038	-
	Magnesia	270	-	0.067	-
	Asbestos	470-570	0.82	0.154	-

Source: C.P. Arora

The heat transfer through outside air to outer surface of wall and inside surface to inside air is equivalent to the actual heat transfer by convection. So the air film coefficient depends upon air velocity, as convection heat transfer depends upon air movement the outside air film coefficient h_o is higher than inside air film coefficient h_i due to limited air movement in the room. The value of surface conductance for air film is given in Table 3.4.

Table 3.4 Surface or film conductance for air film

Air velocity	Surface position	**Direction of heat flow**	**Surface emissivity**		
			0.9	**0.7**	**0.5**
Still air	Horizontal	Up	9.4	5.2	4.4
Still air	Horizontal	Down	6.3	2.2	1.3
Still air	Vertical	Horizontal	8.5	4.3	3.5
25 kmph	Any position	Any	35	----	----
12 kmph	Any position	Any	23.3	----	----

Source: C.P. Arora

Table 3.5 gives the thermal conductance for air space of three widths with different orientations and at two different mean temperatures.

Table 3.5 Thermal conductance k_a of air space

Mean temperature	**Position**	**Direction of heat flow**	**Widths cm**	**Conductance W/m^2-^oC**
10 ^oC	Horizontal	Up	2.1	6.7
			11.6	6.2
		Down	2.1	5.7
			4.2	5.1
			11.6	4.8
	Vertical	Horizontal	2.1	5.8
			11.6	5.8
32 ^oC	Horizontal	Up	2.1	7.7
			11.6	7.2
		Down	2.1	7.0
			4.2	6.2
			11.6	5.8
	Vertical	Horizontal	2.1	7.0
			11.6	6.9

Source: C.P. Arora

3.2.1.1.2 Surface area

The area of wall is calculated after deducting the area of the opening for door and windows.

3.2.1.1.3 Cooling load temperature difference (CLTD)

CLTD is the effective temperature difference across a wall or ceiling, which accounts for the effect of radiant heat as well as the temperature difference. The ASHRAE has developed the CLTD values for exterior walls and roofs based on solar radiation variation typical of 40°N latitude on July 21 with a certain outside and inside air temperature conditions and based on building materials commonly used in North America. The accuracy of the CLTD values could be not accurate, when the location of the building is not at 40°N (especially below 24°N). The LM is correction factor for the locations other than 40°N latitude. As Rourkela is located on 22.12°N Latitude, the closest value of corrected factor is taken as latitude of 24. The value of equivalent CLTDs for D type of wall are given in table 3.6

Table 3.6 Equivalent CLTDs for D type of walls

Wall facing	**Solar time hr.**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
N	8	7	7	6	5	4	3	3	3	3	3	4	4	6
NE	9	8	7	6	6	4	4	4	6	8	9	11	12	13
E	11	9	8	7	6	5	4	5	7	9	12	15	17	18
SE	11	9	8	7	6	6	4	4	6	7	9	12	14	16
S	11	9	8	7	6	5	4	4	3	3	4	5	7	9
SW	16	14	12	11	9	8	7	6	5	4	4	4	6	7
W	17	15	13	12	10	8	7	6	6	5	5	5	6	6
NW	14	12	11	9	8	7	6	5	4	4	4	4	5	6

Wall facing	**Solar time hr.**										**Hr. of Max CLTD**	**Max CLTD**	**Min CLTD**
	15	16	17	18	19	20	21	22	23	24			
N	7	7	8	9	10	11	11	11	10	9	21	11	3
NE	13	13	13	14	14	13	13	12	11	10	19	14	4
E	18	18	18	18	17	17	16	14	13	12	16	18	4
SE	17	12	18	18	17	17	16	14	13	12	17	18	4
S	11	13	15	16	16	16	15	14	13	12	19	16	3
SW	9	12	15	18	20	21	21	21	19	17	21	21	4
W	8	10	13	17	20	22	23	22	21	19	21	23	5
NW	7	8	10	12	15	17	18	18	17	15	22	18	4

The CLTD values for all other wall groups can be referred in the 1997 ASHRAE *Fundamentals Handbook.*

Table 3.6 gives value for particular latitude, time of the year, color of the wall, temperature difference between outside design and inside design conditions and variation in outside design temperature. The values shown in Table 3.6 assume a mean temperature of 29.4 ^{o}C, room temperature 24.5 ^{o}C, dark surface, and a clear sky. For CLTD value of different kinds of roof and ceilings we can refer ASHRAE hand books, For different design conditions, the CLTD values given in Table 3.6 must be corrected before used in heat transfer equations. The following equation can be used for correct CLTD.

$$CLTD_{corr} = (CLTD + LM)\,K + (25.5 - Ti) + (To - 29.4) \quad \text{……….. (3.3)}$$

Where To = outside design temperature (^{o}C)

Ti = inside design temperature (^{o}C)

LM = latitude month correction given table 3.7

K = correction factor depends on building color.

K = 1 for dark color, 0.85 for medium color and 0.65 for light color.

When types of wall is thermally heavier then group A type of wall due to added insulation, then uncorrected CLTD is given in Table 3.7

Table 3.7 CLTD when wall is heavier

N	NE	E	SE	S	SW	W	NW
6	9	12	12	9	12	12	9

Table 3.8 latitude month correction (LM) value for 24^{o}N

Month	N	NE/NW	E/W	SE/SW	S	HOR
Dec	-5	-8	-7	3	13	-13
Jan/Nov	-4	-9	-6	3	13	-11
Feb/Oct	-4	-6	-3	3	10	-7
March/Sept	-3	-3	-1	1	4	-3
Apr/Aug	-2	0	-1	-1	-3	0
May/Jul	1	2	0	-3	-6	1
Jun	3	3	0	-4	-6	1

3.2.1.2 Heat Gain through Glass

Heat is transmitted through glass due to solar radiation. The heat gain through glass areas constitutes a major portion of the load on the cooling apparatus. This could be direct in the form of sunrays or diffused radiation due to reflection from other objects outside. Heat transmitted through a glass depends on the wavelength of radiation and physical and chemical characteristics of glass. Part of the radiation is absorbed, part is reflected and the rest is transmitted. The heat transfer of glass takes place in the two ways, transmission heat gain and solar heat gain. The following equations are used to calculate heat gain from glass areas.

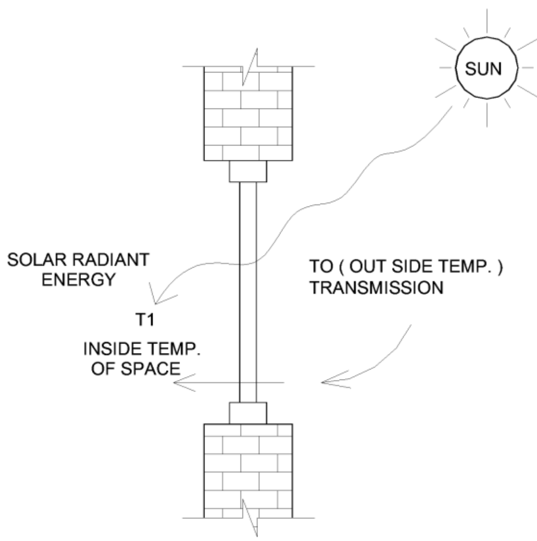


Fig 3.4 *heat gain through glass*

Transmission heat gain through glass:

$$Q = UA(CLTD)_{corr} \qquad \ldots\ldots\ldots\ldots\ldots (3.4)$$

By solar radiation:

$$Q = A \times SHGF_{\max} \times SC \times CLF \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

$SHGF_{\max}$ = maximum solar heat gain factor (W/m^2)

SC = shading coefficient depends on type of shading

CLF = cooling load factor

Table 3.9 gives the value of sensible heat gain factor for 22^o North latitude at different orientations and months.

Table 3.9 $SHGF_{max}$ for 22^o N latitude

Months	Maximum solar heat gain factor W/m^2					
	N	NE/NW	E/W	SE/SW	S	HOR
January	82	129	568	726	640	647
February	88	243	647	697	533	744
March	98	372	685	609	366	811
April	110	473	662	476	192	826
May	129	527	631	372	129	820
June	167	543	612	328	123	811
July	136	520	618	360	129	808
August	114	461	640	457	205	785
September	104	356	650	587	360	729
October	91	240	621	675	517	644
November	82	129	558	722	631	353
December	79	91	533	729	672	647

The maximum solar heat gain factor $SHGF_{max}$ and CLF depends on latitude, orientation and month, it is totally solar heat transmission which includes directly transmitted energy and indirectly transferred heat gain energy. The cooling load factor (CLF) for different orientation and months are given on in Table 3.10.

Table 3.10 Cooling load factor (CLF) for windows glass with indoor shading device

Wall facing	Solar time hr.											
	1	2	3	4	5	6	7	8	9	10	11	12
N	0.08	0.07	0.06	0.06	0.07	0.73	0.66	0.65	0.73	0.8	0.86	0.89
NE	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27
E	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.8	0.76	0.62	0.41	0.27
SE	0.03	0.03	0.02	0.02	0.02	0.3	0.57	0.74	0.81	0.79	0.68	0.49
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38
W	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17
NW	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.2	0.21
HOR	0.06	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85

Table 3.10 continues…..

Wall facing	Solar time hr.											
	13	14	15	16	17	18	19	20	21	22	23	24
N	0.89	0.86	0.82	0.75	0.78	0.91	0.24	0.18	0.15	0.13	0.11	0.10
NE	0.26	0.24	0.22	0.20	0.16	0.12	0.06	0.05	0.04	0.04	0.03	0.03
E	0.24	0.22	0.20	0.17	0.14	0.11	0.06	0.05	0.05	0.04	0.03	0.03
SE	0.33	0.28	0.25	0.22	0.18	0.13	0.08	0.07	0.06	0.05	0.04	0.04
S	0.80	0.68	0.50	0.35	0.27	0.19	0.11	0.09	0.08	0.07	0.06	0.05
SW	0.59	0.75	0.81	0.81	0.69	0.45	0.16	0.12	0.10	0.09	0.07	0.06
W	0.31	0.53	0.72	0.82	0.81	0.61	0.16	0.12	0.10	0.08	0.07	0.06
NW	0.22	0.30	0.52	0.73	0.82	0.69	0.16	0.12	0.10	0.08	0.07	0.06
HOR	0.85	0.81	0.71	0.58	0.42	0.25	0.14	0.12	0.10	0.08	0.07	0.06

3.1.2.3 Heat Gain from Occupants

The human body in a cooled space constitute cooling load of sensible and latent heat. In an air conditioned room, sensible heat load given out is due to temperature different between body and room air. The heat gain from occupants is based on the average number of people that are expected to be present in a conditioned space. The heat load produced by each person depends upon the activity of the person. The value of heat gain increases with increase in activity of the human being.

The heat gain from occupancy or people are calculated by following equations:

Sensible heat gain from occupants

$$Q_{s,person} = q_{s,person} \times N \times CLF \qquad \text{…………….. (3.6)}$$

Latent heat gain from occupants

$$Q_{l,person} = q_{l,person} \times N \qquad \text{……………….. (3.7)}$$

Where

$q_{s,person}$ = sensible heat gain/person (W)

$q_{l,person}$ = latent heat gain/person (W)

N = total number of people present in conditioned space

CLF = cooling load factor

Table 3.11lists the rate of heat gain from occupants at different activity level based on 24 ^{o}C room dry bulb temperature.

Table 3.11 *Rate of heat gain from occupant at conditioned space (W)*

Degree of activity	**Typical application**	**Total heat**		**Sensible heat**	**Latent heat**
		Adult, Male	Adjusted		
Seated at Theater	Theater, matinee	115	95	65	30
Seated, very light work	Offices, hotels, apartments	130	115	70	45
Moderately active office work	Offices, hotels, apartments	140	130	75	55
Standing, light work; walking	Department store; retail store	160	130	75	55
Walking, standing	Drug store, bank	160	145	75	70
Sedentary work	Restaurants	145	160	80	80
Light bench work	Factory	235	220	80	140
Moderate dancing	Dance hall	265	250	90	160
Bowling	Bowling alley	440	425	170	255
Heavy work	Factory	440	425	170	255
Athletics	Gymnasium	585	525	210	315

CLF is the cooling load factor for the occupants and it is depends on the people spending time in the conditioned space, and the time intervened since first entering. CLF is equal to 1, if cooling system does not run 24 hr. a day and for auditorium, theater or when people density is high such as for more than 100 people/90m^2. Human body generates both sensible and latent heat load according to activity level. The sensible heat rate increases slightly with higher activity, but latent heat increases dramatically because of greater perspiration rates needed to maintain body temperature. Because of thermal mass affects the entire sensible heat rate from people is not immediately converted in to cooling load, therefore CLF correction must be applied in sensible heat gain. The latent component is immediately converted to cooling load so no CLF correction is necessary. The value of CLF for occupants are given in Table 3.12

***Table 3.12** Sensible heat cooling load factor (CLF) for people*

Total hrs. in space	Hrs. after each entry into space											
	1	2	3	4	5	6	7	8	9	10	11	12
2	0.49	0.58	0.17	0.13	0.10	0.08	0.07	0.06	0.05	0.04	0.04	0.03
4	0.49	0.59	0.66	0.71	0.27	0.21	0.16	0.14	0.11	0.10	0.08	0.07
6	0.50	0.60	0.67	0.72	0.76	0.79	0.34	0.26	0.21	0.18	0.15	0.13
8	0.51	0.61	0.67	0.72	0.76	0.80	0.82	0.84	0.38	0.30	0.25	0.21
10	0.53	0.62	0.69	0.74	0.77	0.80	0.83	0.85	0.87	0.89	0.42	0.34
12	0.55	0.64	0.70	0.75	0.79	0.81	0.84	0.86	0.88	0.89	0.91	0.92
14	0.58	0.66	0.72	0.77	0.80	0.83	0.85	0.87	0.89	0.90	0.91	0.92
16	0.62	0.70	0.75	0.79	0.82	0.85	0.87	0.88	0.90	0.91	0.92	0.93
18	0.66	0.74	0.79	0.82	0.85	0.87	0.89	0.90	0.92	0.93	0.94	0.94

Total hrs. in space	Hrs. after each entry into space											
	13	14	15	16	17	18	19	20	21	22	23	24
2	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01
6	0.11	0.10	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03
8	0.18	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.06	0.05	0.05	0.04
10	0.28	0.23	0.20	0.17	0.15	0.13	0.11	0.10	0.09	0.08	0.07	0.06
12	0.45	0.36	0.30	0.25	0.21	0.19	0.16	0.14	0.12	0.11	0.09	0.08
14	0.93	0.94	0.47	0.38	0.31	0.26	0.23	0.20	0.17	0.15	0.13	0.11
16	0.94	0.95	0.95	0.96	0.49	0.39	0.33	0.28	0.24	0.20	0.18	0.16
18	0.95	0.96	0.96	0.97	0.97	0.97	0.50	0.40	0.33	0.28	0.24	0.21

3.1.2.4 Heat Gain from Lighting Equipments

Electric lights generate sensible heat equal to the amount of the electric power consumed. The heat gained from electric light depends upon the rating of light in watts, use factor and allowance factor. As a rough calculation, one may use the lighting load equal to 33.5 W/m^2 to produce a lighting standard of 540 lumens/m^2 in an office space. After the wattage is known the heat gain from electric light is given by Eqn. (3.8)

$$Q_{light} = \textit{Total wattage of light} \times \textit{Use factor} \times \textit{Allowance factor} \ldots\ldots\ldots\ldots \text{(3.8)}$$

The use factor is the ratio of actual wattage in use to installed wattage. Its value depends upon the type of use to which room is put. In case of residences, commercial stores and shops, its value is usually taken as unity, whereas for industrial workshops it is taken below 0.5. The allowance factor is generally used in the case of fluorescent light to allow for the power used by the ballast. Its value is taken as 1.25. The value of wattage of light is given in Table 3.13 according to the type of use in room

Table 3.13 Typical lighting load

Description of rooms	Lighting power W/m^2
Office room	12
Conference/Meeting/Multipurpose	14
Classroom/Lecture/Training	15
Audience/Seating area	10
Dining area	10
Laboratory	15
Rest room	10
Electrical/mechanical room	16
Workshop	20
Library, reading area	13

3.1.2.5 Heat gain from electric equipments

The general electric equipments and appliances such as typewriters, computers, printers, fax machines, TV, refrigerator, washing machines, kitchen equipments and any other equipments of this type also adds heat in the air conditioning space and it is handled in a similar manner as lighting. The heat gain by the equipment is determined by the wattage of the equipment and is calculated by:

$$Q_{equipement} = \quad Total\ wattage\ of\ equipment \times Use\ factor \times CLF \ldots\ldots\ldots\ldots \text{(3.9)}$$

CLF = 1.0, if operation is 24 hours or of cooling is off at night or during weekends.

3.1.2.5.1 Heat gain from office equipments

General office equipments such as computers, printers, fax machines and copiers consume energy even when these are not in use. With the common use of desktop computers, printers and other devices also add heat in conditioned space. The Table 3.14 provides a sample of typical electrical power requirements for common office equipment. For details refer to *2001 ASHRAE Fundamentals Hand Book,*

Table 3.14 Heat gain rate for office equipments (Watts)

Appliance	Continuous	Average	Ideal
Computer -15" Monitor	110		20
-17" Monitor	125		25
-19" Monitor	135		30
Laser printer-Desktop	130	100	10
-Small office	320	160	70
-Large office	550	275	125
Fax machine		30	
Facsimile Machine	30		15
Image Scanner	25		15
Dot Matrix Printer	50		25
Desktop Copier	400	85	20
Office Copier	1100	400	300

3.1.2.6 Heat gain due to Infiltration

Infiltration may be defined as the uncontrolled entry of untreated, outdoor air directly into the conditioned space in other words infiltration air is the air that enters a conditioned space through windows crack and opening and closing of doors. This is caused by pressure difference between the two sides of the windows and doors and it depends upon the wind velocity and its direction and difference in densities due to the temperature difference between the inside and outside air. For calculating the quantity of infiltration air generally air change method is use. According to this method, the amount of infiltrated air is calculated by equation

$$\text{Amount of infiltrated air } (V_{inf}) = \frac{Valume\ of\ space \times A_C}{60}\ \text{m}^3/\text{min}\ldots\ldots\ldots (3.10)$$

Where A_C is number of air changes value/ hour and its value is given in table 3.15

The total room infiltration air for an entire building is taken one-half of the above calculated value because infiltration takes place on the windward side of building. In multi- story buildings which are fully air conditioned, stack effect cause infiltration/exfiltration. In summer, due to cold air column inside, exfiltration may take place at lower floor and infiltration in upper floor. In winter the phenomenon is reversed.

Table 3.15 Number of air changes per hour.

Kind of room or building	**Number of air changes per hour(A_C)**
Room with no windows or outside doors	0.5 to 0.75
Room, one wall exposed	1
Room, two walls exposed	1.5
Room, three walls exposed	2
Room, four walls exposed	2
Entrance halls	2 to 3
Reception halls	2

The sensible heat gain due to the infiltration is given by Eqn (3.11)

$$Q_{S,\inf} = 20.44 \times V_{\inf} \times (T_o - T_i) \text{ Watts} \qquad \text{……………. (3.11)}$$

And the latent heat gain due to the infiltration is given by Eqn (3.12)

$$Q_{L,\inf} = 50000 \times V_{\inf} \times (W_o - W_i) \text{ Watts} \qquad \text{……………. (3.12)}$$

Where

T_o and T_i = Outside and inside design temperature respectively (^oC)

W_o and W_i = specific humidity of outside and inside at conditioned space (kg/kg of dry air)

3.1.2.7 Heat gain due to Ventilation

Human beings inside a space require freshness to air. It has been seen in studies by the ASHRAE, that, inadequate fresh air supply to a space leads to health problems for people inside it. This is called '*Sick building syndrome'*. The ventilation is provide to the conditioned space in order to minimize odor, concentration of smoke, carbon dioxide and other undesirable gases, so that freshness of air could be maintained. The quantity of outside air used for ventilation should provide at least one-half air change per hours in building with normal ceiling height. Also, if the infiltration air quantity is larger than the ventilation quantity, then the latter should be decreased to at least equal to the infiltration air. The outside air adds sensible as well as latent heat.

Therefore, the ASHRAE gives the minimum and recommended values of fresh air per person for different applications of space. Thus, in a hospital room the ventilation requirement is less than that for a conference room. The table also takes in to account density of people inside the space by recommending the values per m^2 floor area. In case of private rooms with a low occupation density it gives more acceptable value of ventilation requirements.

Table 3.16 Required Ventilation rate per Person and per Area

Description	Default occupant density ppl/100m^2	Outdoor air m^3/min/person	Outdoor air m^3/min/m^2 area
Auditorium seating area	20	0.15	0.05
Classrooms (age 9 plus)	35	0.30	0.04
Computer lab	25	0.30	0.04
Lecture classroom	65	0.23	0.02
Library	10	0.15	0.04
Lobbies	150	0.15	0.02
Multi-purpose assembly	120	0.15	0.02
Office space	5	0.15	0.02
Reception area	30	0.15	0.02

3.3 Total Loads

The sum of total room sensible heat gain and total room latent heat gain is known as room total heat load.

$$RTH = RSH + RLH \qquad \text{…………… (3.13)}$$

3.3.1 Total Room Sensible Heat Gain

Room sensible heat gain is a combination of all type of sensible heat gain at a conditioned space i.e.

RSHG = Sensible heat gain through walls, floors and ceilings + Sensible heat gain through glasses + Sensible heat gain due to occupants + Sensible heat gain due to infiltration air + Sensible heat gain due to ventilation + Sensible heat gain due to lights and fans.

……………………… (3.14)

3.3.2 Total Room Latent Heat Gain

Room latent heat gain is a combination of all type of latent heat gain at a conditioned space i.e.

RLHG = Latent heat gain due to infiltration + Latent heat gain due to ventilations + Latent heat gain from persons + Latent heat gain due to appliances. ……...………. (3.15)

3.3.3 Room Sensible Heat Factor

Room sensible heat factor is defined as the ratio of the room sensible heat to the room total heat. Mathematically, room sensible heat factor

$$RSHF = \frac{RSH}{RSH + RLH} = \frac{RSH}{RTH} \qquad \text{…………………. (3.16)}$$

3.3.4 Total Load in tons

Total heat gain obtained by all above modes is in Watts and we can convert this value from Watts to tons with help of Eqn (3.17)

$$Total\ load\ in\ tons = \frac{Total\ load\ in\ Watts}{35000} \qquad \text{……………….. (3.17)}$$

CHAPTER 4

THERMAL LOAD CALCULATION FOR THE TIIR BUILDING

4.1 Heat Transfer Analysis

In any building, heat is transmitted through external walls, top roof, floor of the ground floor, windows and doors. Heat transfer takes place by conduction, convection and radiation. The cooling load of the building is dependent on local climate, thermal characteristics of material and type of building. For cooling load calculation, there are many types of software such as DOE 2.1E, BLAST, Elite or HAP 4.3 available which use the transfer functions method and heat balance method. These methods require a complex and lengthy data input. Therefore, most of the designers do not use these methods. They prefer a more compact and easy method for calculating the cooling load of a building. A more basic version for calculating a cooling load using the transfer function method is to use the one step procedure, which was first presented in the ASHRAE Handbook of Fundamentals in the year 2005. This method is called the cooling load temperature differences (CLTD) method. In this method, hand calculation is used to calculate cooling load.

Hand calculations were done for a small portion of the building using the all equations mention in Chapter 3 and calculation procedures and information. In the TIIR building there are total 19 rooms of four floors where air conditioning is required including auditorium, lecture rooms, meeting rooms, library etc. Each one of them is treated as separate system. All equations required for heat transfer through the building and for the inside's load were used to get the thermal load. Then, all the equations were inserted in a particular program MS Excel, to get the results.

The general step by step procedures for calculating the total heat load are as follows

i. Select inside design condition (Temperature, relative humidity).
ii. Select outside design condition (Temperature, relative humidity).
iii. Determine the overall heat transfer coefficient U_o for wall, ceiling, floor, door, windows, below grade.
iv. Calculate area of wall, ceiling, floor, door, windows.
v. Calculate heat gain from transmission.
vi. Calculate solar heat gain

vii. Calculate sensible and latent heat gain from ventilation, infiltration and occupants.
viii. Calculate lighting heat gain
ix. Calculate total heat gain and
x. Calculate TR

4.2 Design condition

The amount of cooling that has to be accomplished to keep buildings comfortable in summer and winter depends on the desired indoor conditions and on the outdoor conditions on a given day. These conditions are, respectively, called the "indoor design condition" and the "outdoor design condition".

For most of the comfort systems, the recommended indoor temperature and relative humidity are as follows

DBT – 22.78 ^{o}C to 26.11 ^{o}C, and RH – 50% for summer

DBT – 22.11 ^{o}C to 22.22 ^{o}C and RH – 20 to 30% for winter

The cooling load of the TIIR building is based on 25 ^{o}C dry bulb temperature and 50% relative humidity Indoor design conditions.

The outdoor design conditions are determined from published data for the specific location, based on weather bureau or airport records. The outdoor design conditions of Rourkela is 43 ^{o}C DBT and Relative Humidity 46% for summer (month of May) and 36 ^{o}C DBT and 84 % RH for monsoon (month of July).

4.3 Overall heat transfer coefficient calculation

Commonly the building walls may consist of non-homogeneous materials for example hollow bricks, air gap and plaster. Heat transfer through these types of wall is quite complicated as it involves simultaneous heat transfer by conduction, convection and radiation as shown on Fig 3.3 in Chapter 3. All material has different kinds of thermo-physical properties; the thermo-physical properties of common building materials have been measured and presented in ASHRAE and other handbooks.

4.3.1 Calculation of overall heat transfer coefficient (U_o) for outer walls of TIIR building

The outer walls of the TIIR building consist of combinations of different layers are 230 mm common bricks + air space + 230 mm common bricks with 13 mm cement mortar and 26 mm

(13 mm both side) sand cement plaster, and thermal conductivities and thermal conductance from Table 3.3, Table 3.4 and Table 3.5

Thermal conductivity of brick (k_{brick}) = 0.77 W/m-K

Thermal conductivity of plaster ($k_{plaster}$) = 8.65 W/m-K

Thermal conductance of air gape = 5.8 W/m^2-K

Outside film coefficient = 23 W/m2-K

Inside film coefficient = 8.5 W/m2-K

Now overall heat transfer coefficient from equation 3.2

$$U_{\text{exposed walls}} = \frac{1}{\frac{1}{23}+\frac{0.013}{8.65}+\frac{0.23}{0.77}+\frac{1}{5.8}+\frac{0.23}{0.77}+\frac{0.013}{8.65}+\frac{1}{8.5}} = 1.07 \text{ W/m}^2\text{-K}$$

4.3.2 Overall heat transfer coefficient for inner and partition walls

The interior walls of building are consist of 230 mm common bricks with 26 (13 mm both side) inch sand cement plaster.

$$U_{partition} = \frac{1}{\frac{1}{8.5}+\frac{0.013}{8.65}+\frac{0.23}{0.77}+\frac{0.013}{8.65}+\frac{1}{8.5}} = 1.86 \text{ W/m}^2\text{-K}$$

4.3.3 Overall heat transfer coefficient of roof

The roofs consist of 152 mm concrete poured in metal sheet with 13 mm plaster

$$U_{ceiling} = \frac{1}{\frac{1}{9.4}+\frac{0.154}{1.73}+\frac{0.013}{8.65}+\frac{1}{6.3}} = 2.82 \text{ W/m}^2\text{-K}$$

4.3.4 Overall heat transfer coefficient of floor

$$U_{flloor} = \frac{1}{\frac{1}{9.4}+\frac{0.2}{1.73}} = 4.5 \text{ W/m}^2\text{-K}$$

4.3.5 Overall heat transfer coefficient of window glass

$$U_{glass} = \frac{1}{\frac{1}{23}+\frac{0.0127}{0.78}+\frac{1}{8.5}} = 5.6 \text{ W/m}^2\text{-K}$$

4.4 Calculation of Cooling Load Temperature Difference

The expose walls of the TIIR (Technology Innovation and Industry Relation) building are thermally heavier than the group A type wall due to added insulation, then uncorrected CLTD of the wall from Table 3.7

Table 4.1 Corrected CLTD values for TIIR building

CLTD	K	LM	T_o (°C)		T_i (°C)	$CLTD_{corr}$ = (CLTD + LM) K + (25.5 – Ti) + (To – 29.4)	
			Summer	Monsoon		Summer (May)	Monsoon (July)
6	1	1	43	36	25	23	16
9	1	2	43	36	25	28	21
12	1	0	43	36	25	28	21
12	1	-3	43	36	25	25	18
9	1	-6	43	36	25	20	13
12	1	-3	43	36	25	25	18
12	1	0	43	36	25	28	21
9	1	2	43	36	25	28	21
30.0	1	1	43	36	25	47	40

4.5 Calculation of heat transfer area

In the TIIR building there are total 19 rooms of four floors where air conditioning is required including auditorium, lecture rooms, meeting rooms, library etc. Each one of them is treated as separate system. The detailed of AC requirement area is given in Table 4.2

Table 4.2 AC Requirement areas in the TIIR building

TIIR BUILDING						
GROUND FLOOR						
S.N.	**Room/ Hall**	**Width (m)**	**Length (m)**	**Area (m^2)**	**Celling Ht (m)**	**AC Requirement**
1	120 seat Lecture room	14.17	8.67	122.85	3.40	122.85
2	Direct TIIR	3.57	6.87	24.53	3.40	24.53
3	Admin Office	5.27	6.87	36.20	3.35	36.20
4	Placement office	2.97	6.87	20.40	3.40	20.40
5	IPR Office	5.27	6.87	36.20	3.35	36.20

6	Professor	3.57	6.87	24.53	3.40	24.53
7	120 seat Lecture room	14.17	8.67	122.85	3.40	122.85
8	Office room	12.27	6.97	85.52	3.40	85.52
9	Meeting room	12.27	6.97	85.52	3.40	85.52
10	Central Workshop	14.17	19.97	282.97		
11	Library	6.97	6.47	45.10	3.32	45.10
12	Dining	9.67	6.97	67.40		
13	Alumini Relation	6.97	6.97	48.58	3.32	48.58
14	Alumini Visitors	6.97	12.74	88.80	3.32	88.80
15	Placement Cell	14.17	19.97	282.97		
					Sub Total	741.09
FIRST FLOOR						
1	Common Facilities	14.04	20.09	282.06		
2	Interview Room	5.23	6.97	36.45	3.35	36.45
3	Interview Room	9.07	6.97	63.22	3.35	63.22
4	Working Modules	14.04	8.77	123.13		
5	Working Modules	12.53	6.97	87.33		
6	Seminar Room	12.53	6.97	87.33	3.35	87.33
7	Placement Cell	14.04	20.08	281.92		
8	Working Modules	6.97	6.66	46.42		
9	Working Modules	6.97	6.00	41.82		
10	Working Modules	6.97	6.97	48.58		
11	Working Modules	6.97	6.97	48.58		
12	Working Modules	6.97	6.97	48.58		
13	Working Modules	6.97	6.00	41.82		
14	Working Modules	6.97	6.66	46.42		
15	Central Design Office	14.17	20.09	284.68	3.32	284.68
16	Auditorium	20.00	25.00	500.00	7.55	500.00

					Sub Total	**971.6804**
SECOND FLOOR						
1	Working Modules	14.17	8.67	122.85		
2	Library Facilities	9.07	6.87	62.31	3.35	62.31
3	Working Modules	9.07	6.87	62.31		
4	Working Modules	14.17	8.67	122.85		
5	Working Modules	12.27	6.97	85.52		
6	Working Modules	12.27	6.97	85.52		
7	Working Modules	14.17	19.97	282.97		
8	Working Modules	6.97	6.43	44.82		
9	Working Modules	6.97	6.00	41.82		
10	Working Modules	6.97	6.97	48.58		
11	Working Modules	7.20	6.97	50.18		
12	Working Modules	9.44	6.97	65.80		
13	Working Modules	6.97	6.00	41.82		
14	Working Modules	6.97	6.66	46.42		
15	Working Modules	14.17	19.97	282.97		
					Sub Total	**62.31**
THIRD FLOOR						
1	Working Modules	14.17	8.67	122.85		
2	Working Modules	9.07	6.87	62.31		
3	Working Modules	9.07	6.87	62.31		
4	Working Modules	14.17	8.67	122.85		
5	Working Modules	12.27	6.97	85.52		
6	Working Modules	12.27	6.97	85.52		
7	Working Modules	14.17	19.97	282.97		
8	Working Modules	6.97	6.43	44.82		
9	Working Modules	6.97	6.00	41.82		
10	Working Modules	6.97	6.97	48.58		
11	Working Modules	7.20	6.97	50.18		
12	Working Modules	9.44	6.97	65.80		
13	Working Modules	6.97	6.00	41.82		
14	Working Modules	6.97	6.66	46.42		
15	Working Modules	14.17	19.97	282.97		
					Sub Total	**0**
					Total	**1775.1**

4.5.1 Dimension of the doors and windows

All dimension of the doors and windows are given in Table 4.3

Table 4.3 dimension of doors and windows

S.No	Type Mark	Width	Height	Description
1	D1	2.00	2.70	Flush Door
2	D2	1.20	2.70	Flush Door
3	D3	1.00	2.70	Flush Door
4	D4	1.50	2.70	Flush Door
5	D5	0.90	2.70	Flush Door
6	W1	1.50	1.80	UPVC Window
7	W2	2.40	1.80	UPVC Window
8	W3	3.00	1.80	UPVC Window
9	W4	3.60	1.80	UPVC Window
10	W5	3.00	1.20	UPVC Window
11	OP1	1.50	1.80	Low Wall with Hand Drill
12	OP2	2.47	1.80	Low Wall with Hand Drill

4.6 Total Cooling Load Calculations

4.6.1 Cooling load calculation of 120 Seated Lecture Room 1

Length of the room = 14.17 m

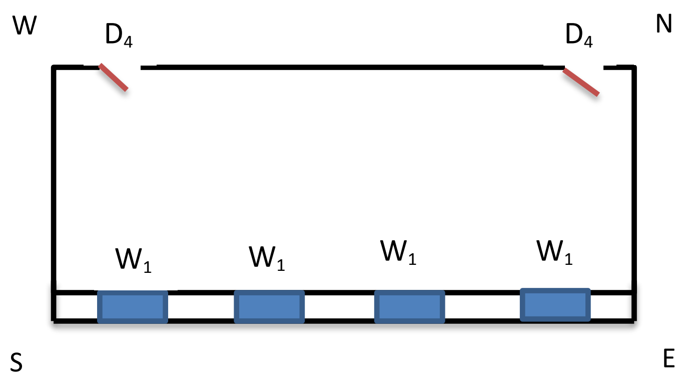
Width of the room = 8.67 m

Height of the room = 3.40 m

Area of glass (W_1) = $1.5 \times 1.8 = 2.7\ \text{m}^2$

Area of the door (D_4) = $1.5 \times 2.7 = 4.05\ \text{m}^2$

Total sun facing glass area = $2.7 \times 4 = 10.8\ \text{m}^2$



Sun facing wall

Outside wall area (SE) = $14.17 \times 3.4 - 4 \times 2.7 = 37.38\,\text{m}^2$

Partition wall areas (NE, NW, SW) = $8.67 \times 3.4 + 8.67 \times 3.4 + (14.17 \times 3.4 - 2 \times 4.05) = 99.034\ \text{m}^2$

Now the amount of infiltrated air through windows and walls is

$$= \frac{14.17 \times 8.67 \times 3.4 \times 1}{60} = 6.97\ \text{m}^3/\text{min}$$

The details of cooling load calculations of the 120 seated lecture room 1 are given on the calculation sheet in Table 4.4

Table 4.4 Cooling load sheet of 120 seated Lecture Room 1

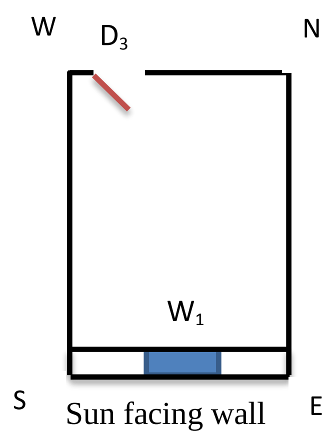
	:		**Area**	:	**NIT ROURKELA**
Job No.	:	1	**City**	:	**Rourkela / Odisha**
Project	:	**TIIR BUILDING COOLING LOAD**	**Month**	:	**May for Summer and July for Monsson**
Space	:	**120 SEAT LECTURE ROOM 1**	**Time**		

Length	(m)	=	14.17		**Summer**				**Monsoon**			
Width	(m)	=	8.67	**CONDITION**	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height	(m)	=	3.40	**Outside**	43	32	46	0.0248	36	33	84	0.03122
Area	(m^2)	=	123	**Inside**	23	16	50	0.00866	23	16	50	0.00866
Volume	(m^3)	=	418	**Difference**	20			0.0161	13			0.0226
BPF		=	0.12	No of Air Changes / Hr.		= 1.00			**filtrated Air(m3/mi**			7

			SUMMER		**Monsoon**	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	10.8	0.14	372	563	360	544
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	37.4	1.07	26	1,045.00	18	711.02
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	10.8	5.60	20	1,209.60	13	786.24
Partition 1	107	1.86	15	2991	8	1595.1
Ceiling	123	2.82	15	5,196.72	8	2,771.58
Floor	123	4.50	2.5	1382	2.3	1271.5
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
7	1	20.44	20	2845.95	13	1849.87
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	121	70		8470		8470
Lights(W/m2)	15	123		1843		1843
Motor (KW)				0		0
Equipment (KW)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**25545.89**		**19841.95**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	1532.75		1190.52	
		ROOM SENSIBLE HEAT (R.S.H.) :	**27078.65**		**21032.47**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
7	1	50000	0.01611	5607.67	0.0226	7852.82
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	121	45		5445		5445
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	552.63		664.89	
		ROOM LATENT HEAT (R.L.H.) :	**11605.30**		**13962.71**	
		ROOM TOTAL HEAT (R.T.H.) :	**38683.95**		**34995.18**	

OUTSIDE AIR HEAT:						
			OUTSIDE AIR SENSIBLE HEAT (OASH)			
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.5	0.88	20.44	20	883.92	13	574.55
			OUTSIDE AIR LATENT HEAT (OALH)			
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
2.5	0.88	50000	0.0161	1741.68	0.0226	2438.99
		SUBTOTAL :	**41309.54**		**38008.72**	
		R.A.heat, leak gain& Safety factor (5%)	2065.48		1900.44	
		GRAND TOTAL :	**43375.02**		**39909.16**	
		TONS = {(W)/3500} :	**12.39**		**11.40**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.70		0.60	
		INDICATED ADP :	8.00		7	
		SELECTED ADP :	**9.00**		**7.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	12.32		16.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**108**		**64**	
		Safety factor (5%)	5		6	
		TOTAL DEHUMIDIFIED AIR:	**113**		**71**	

4.6.2 Cooling load calculation of the Direct TIIR Room



Length of the room = 3.57 m

Width of the room = 6.87 m

Height of the room = 3.40 m

Area of glass (W_1) = $1.5 \times 1.8 = 2.7$ m^2

Area of the door (D_3) = $1.0 \times 2.7 = 2.7$ m^2

Outside wall area (SE) = $3.57 \times 3.4 - 2.7 = 9.44 m^2$

Partition wall areas (NE, SW, NW) = $6.87 \times 3.4 + 6.87 \times 3.4 + (3.57 \times 3.4 - 2.7)$ = 56.15 m^2

Now the amount of infiltrated air through windows and walls is

$$= \frac{3.57 \times 6.87 \times 3.4 \times 1}{60} = 1.4 \ m^3/min$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02 \times 24.53 = 0.5 m^3/min$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 12W/m^2

The details of cooling load calculations of the Direct TIIR room are given on the calculation sheet in Table 4.5

Table 4.5 Cooling load sheet of the Direct TIIR Room

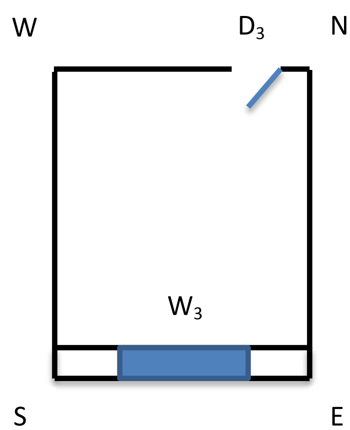
	:		Area	:	NIT ROURKELA
Job No.	:	2	City	:	Rourkela / Orissa
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	DIRECT TIIR	Time		4.00 PM

Length	(m)	=	3.57		Summer				Monsoon			
Width	(m)	=	6.87	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height	(m)	=	3.40	Outside	43	32	46	0.0248	36	33	84	0.03122
Area	(m^2)	=	25	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume	(m^3)	=	83	Difference	20			0.0161	13			0.0226
BPF		=	0.12	No of Air Changes / Hr.		= 1.00			filtrated Air(m3/mi			1.39

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	2.7	0.14	372	141	360	136
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	9.4	1.07	26	263.76	18	179.47
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	2.7	5.60	20	302.40	13	196.56
Partition 1	56	1.86	15	1567	8	835.5
Ceiling	25	2.82	15	1,037.45	8	553.30
Floor	25	4.50	2.5	276	8	882.9
HEAT GAIN DUE TO INFILTRATION						
Outside Air CFM	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.39	1	20.44	20	568.15	13	369.30
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	5	70		350		350
Lights(W/m2)	12	25		294		294
Motor (W)				0		0
Equipment (W)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**4799.28**		**3797.32**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	287.96		227.84	
		ROOM SENSIBLE HEAT (R.S.H.) :	**5087.24**		**4025.16**	
ROOM LATENT HEAT CALCULATIONS:						
Outside Air CFM	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
1.39	1	50000	0.01611	1119.48	0.0226	1567.70
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	5	45		225		225
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	67.22		89.63	
		ROOM LATENT HEAT (R.L.H.) :	**1411.71**		**1882.33**	
		ROOM TOTAL HEAT (R.T.H.) :	**6498.95**		**5907.49**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
0.5	0.88	20.44	20	176.46	13	114.70
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
0.5	0.88	50000	0.0161	347.70	0.0226	486.91
		SUBTOTAL :	**7023.11**		**6509.10**	
		R.A.heat, leak gain& Safety factor (5%)	351.16		325.45	
		GRAND TOTAL :	**7374.26**		**6834.55**	
		TONS = {(W)/3500} :	**2.11**		**1.95**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.78		0.68	
		INDICATED ADP :	9.00		8	
		SELECTED ADP :	**9.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	12.32		15.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**20**		**13**	
		Safety factor (5%)	1		1	
		TOTAL DEHUMIDIFIED AIR:	**21**		**14**	

4.6.3 Cooling load calculation of the Admin Office



Sun facing wall

Length of the room = 5.27 m

Width of the room = 6.87 m

Height of the room = 3.35 m

Area of glass (W_3) = $3\times1.8 = 5.4\ m^2$

Area of the door (D_3) = $1.0\times2.7 = 2.7\ m^2$

Outside wall area (SE) = $5.27\times3.35-5.4=12.25\,m^2$

Partition wall areas (NE, SW, NW) = $6.87\times3.35+6.87\times3.35+(5.27\times3.35-2.7) = 60.98\ m^2$

Now the amount of infiltrated air through windows and walls is

$$=\frac{5.27\times6.87\times3.35\times1}{60}=2.02\ m^3/min$$

Ventilation requirement/m^2 = $0.02\ m^3/min$

Total ventilation required = $0.02\times36.2=0.72\,m^3/min$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = $12W/m^2$

The details of cooling load calculations of the Admin Office are given in Table 4.6

Table 4.6 Cooling load sheet of the Admin Office Room

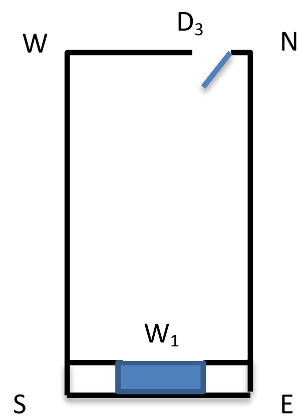
	:		Area	:	NIT ROURKELA
Job No.	:	3	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	ADMIN OFFICE	Time		

				Summer				Monsoon			
Length (m)	=	5.27									
Width (m)	=	6.87	**CONDITION**	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height (m)	=	3.35	**Outside**	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	36	**Inside**	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	121	**Difference**	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.		=	1.00		**filtrated Air(m3/mi**			**2.02**

			SUMMER		**Monsoon**	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	5.4	0.14	372	281	360	272
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	12.3	1.07	26	342.28	18	232.89
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	5.4	5.60	20	604.80	13	393.12
Partition 1	61	1.86	15	1702	8	907.7
Ceiling	36	2.82	15	1,531.47	8	816.78
Floor	36	4.50	2.5	407	2.5	407.3
HEAT GAIN DUE TO INFILTRATION						
Outside Air CFM	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.02	1	20.44	20	826.36	13	537.14
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	6	70		420		420
Lights(W/m2)	12	36		434		434
Motor (W)				0		0
Equipment (W)	180.0			180		180
		ROOM SENSIBLE HEAT SUBTOTAL :	**6729.99**		**4601.25**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	403.80		276.07	
		ROOM SENSIBLE HEAT (R.S.H.) :	**7133.79**		**4877.32**	
ROOM LATENT HEAT CALCULATIONS:						
Outside Air CFM	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
2.02	1	50000	0.01611	1628.27	0.0226	2280.18
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	6	45		270		270
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	94.91		127.51	
		ROOM LATENT HEAT (R.L.H.) :	**1993.18**		**2677.69**	
		ROOM TOTAL HEAT (R.T.H.) :	**9126.97**		**7555.02**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
0.90	0.88	20.44	20	323.77	13	210.45
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
0.90	0.88	50000	0.0161	637.96	0.0226	893.38
SUBTOTAL :			**10088.70**		**8658.84**	
R.A.heat, leak gain& Safety factor (5%)			504.43		432.94	
GRAND TOTAL :			**10593.13**		**9091.78**	
TONS = {(W)/3500} :			**3.03**		**2.60**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.78		0.65	
INDICATED ADP :			10.00		8	
SELECTED ADP :			**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			11.44		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**31**		**16**	
Safety factor (5%)			2		2	
TOTAL DEHUMIDIFIED AIR:			**32**		**17**	

4.6.4 Cooling load calculation of the Placement Office



Sun facing wall

Length of the room = 2.97 m

Width of the room = 6.87 m

Height of the room = 3.4 m

Area of glass (W_1) = $1.5 \times 1.8 = 2.7\ \mathrm{m}^2$

Area of the door (D_3) = $1.0 \times 2.7 = 2.7\ \mathrm{m}^2$

Outside wall area (SE) = $2.97 \times 3.4 - 2.7 = 7.4\,\mathrm{m}^2$

Partition wall areas (NE, SW, NW) = $6.87 \times 3.4 + 6.87 \times 3.4 + (2.97 \times 3.4 - 2.7) = 54.11\ \mathrm{m}^2$

Now the amount of infiltrated air through windows and walls is

$$= \frac{2.97 \times 6.87 \times 3.4 \times 1}{60} = 1.16\ \mathrm{m}^3/\mathrm{min}$$

Ventilation requirement/m^2 $= 0.02\ \mathrm{m}^3/\mathrm{min}$

Total ventilation required = $0.02 \times 20.40 = 0.41\mathrm{m}^3/\mathrm{min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = $12\mathrm{W/m}^2$

The details of cooling load calculations of the Placement Office Room are given in Table 4.7

Table 4.7 Cooling load sheet of the Placement Office Room

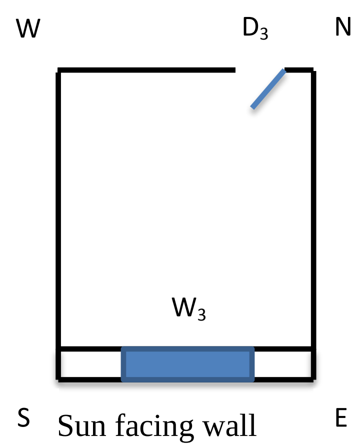
	:	**Area** :	**NIT ROURKELA**
Job No.	: 4	**City** :	**Rourkela / Orissa**
Project	: **TIIR BUILDING COOLING LOAD**	**Month** :	**May for Summer and July for Monsson**
Space	: **PLACEMENT OFFICE**	**Time**	

Length (m)	= 2.97		**Summer**				**Monsoon**			
Width (m)	= 6.87	**CONDITION**	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height (m)	= 3.40	**Outside**	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	= 20	**Inside**	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	= 69	**Difference**	20			0.0161	13			0.0226
BPF	= 0.12	No of Air Changes / Hr.	= 1.00				**filtrated Air(m3/mi**			**1.16**

			SUMMER		**Monsoon**	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	2.7	0.14	372	141	360	136
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	7.4	1.07	26	206.76	18	140.68
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	2.7	5.60	20	302.40	13	196.56
Partition 1	54	1.86	15	1507	8	803.5
Ceiling	20	2.84	15	869.21	8	463.58
Floor	20	4.50	2.5	230	2.5	229.5
HEAT GAIN DUE TO INFILTRATION						
Outside Air CFM	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.16	1	20.44	20	472.66	13	307.23
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	6	70		420		420
Lights(W/m2)	12	20		245		245
Motor (W)				0		0
Equipment (W)	270.0			270		270
ROOM SENSIBLE HEAT SUBTOTAL :			**4662.73**		**3211.90**	
S. A. heat gain, leak loss & Safety Factor (6%) :			279.76		192.71	
ROOM SENSIBLE HEAT (R.S.H.) :			**4942.50**		**3404.61**	
ROOM LATENT HEAT CALCULATIONS:						
Outside Air CFM	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
1.16	1	50000	0.01611	931.34	0.0226	1304.22
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	6	45		270		270
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
S. A. heat gain, leak loss & Safety Factor (5%) :			60.07		78.71	
ROOM LATENT HEAT (R.L.H.) :			**1261.40**		**1652.93**	
ROOM TOTAL HEAT (R.T.H.) :			**6203.90**		**5057.54**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
0.41	0.88	20.44	20	147.50	13	95.87
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
0.41	0.88	50000	0.0161	290.62	0.0226	406.98
		SUBTOTAL :	**6642.02**		**5560.40**	
		R.A.heat, leak gain& Safety factor (5%)	332.10		278.02	
		GRAND TOTAL :	**6974.12**		**5838.42**	
		TONS = {(W)/3500} :	**1.99**		**1.67**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.80		0.67	
		INDICATED ADP :	10.00		8	
		SELECTED ADP :	**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	11.44		15.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**21**		**11**	
		Safety factor (5%)	1		1	
		TOTAL DEHUMIDIFIED AIR:	**22**		**12**	

4.6.5 Cooling load calculation of the IPR Office



Length of the room = 5.27 m

Width of the room = 6.87 m

Height of the room = 3.35 m

Area of glass (W_3) = $3 \times 1.8 = 5.4 \text{ m}^2$

Area of the door (D_3) = $1.0 \times 2.7 = 2.7 \text{ m}^2$

Outside wall area (SE) = $5.27 \times 3.35 - 5.4 = 12.25 \text{ m}^2$

Partition wall areas (NE, SW, NW) = $6.87 \times 3.35 + 6.87 \times 3.35 + (5.27 \times 3.35 - 2.7) = 60.98 \text{ m}^2$

Now the amount of infiltrated air through windows and walls is

$$= \frac{5.27 \times 6.87 \times 3.35 \times 1}{60} = 2.02 \text{ m}^3/\text{min}$$

Ventilation requirement/m^2 = $0.02 \text{ m}^3/\text{min}$

Total ventilation required = $0.02 \times 36.2 = 0.72 \text{ m}^3/\text{min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 12W/m^2

The details of cooling load calculations of the IPR Office Room are given in Table 4.8

Table 4.8 Cooling load sheet of the IPR Office Room

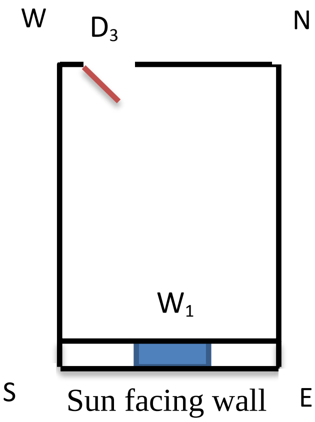
	:		Area	:	NIT ROURKELA
Job No.	:	5	City	:	Rourkela / Orissa
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	IPR OFFICE	Time		

					Summer				Monsoon			
Length	(m)	=	5.27									
Width	(m)	=	6.87	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height	(m)	=	3.35	Outside	43	32	46	0.0248	36	33	84	0.03122
Area	(m^2)	=	36	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume	(m^3)	=	121	Difference	20			0.0161	13			0.0226
BPF		=	0.12	No of Air Changes / Hr.		=	1.00			filtrated Air(m3/mi		2.02

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	5.4	0.14	372	281	360	272
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	12.3	1.07	26	342.28	18	232.89
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	5.4	5.60	20	604.80	13	393.12
Partition 1	61	1.86	15	1702	8	907.7
Ceiling	36	2.82	15	1,531.47	8	816.78
Floor	36	4.50	2.5	407	2.5	407.3
HEAT GAIN DUE TO INFILTRATION						
Outside Air CFM	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.02	1	20.44	20	826.36	13	537.14
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	5	70		350		350
Lights(W/m2)	12	36		434		434
Motor (W)				0		0
Equipment (W)	180.0			180		180
		ROOM SENSIBLE HEAT SUBTOTAL :	6659.99		4531.25	
		S. A. heat gain, leak loss & Safety Factor (6%) :	399.60		271.87	
		ROOM SENSIBLE HEAT (R.S.H.) :	7059.59		4803.12	
ROOM LATENT HEAT CALCULATIONS:						
Outside Air CFM	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
2.02	1	50000	0.01611	1628.27	0.0226	2280.18
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	5	45		225		225
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	92.66		125.26	
		ROOM LATENT HEAT (R.L.H.) :	1945.93		2630.44	
		ROOM TOTAL HEAT (R.T.H.) :	9005.52		7433.57	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
0.72	0.88	20.44	20	259.02	13	168.36
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
0.72	0.88	50000	0.0161	510.36	0.0226	714.70
SUBTOTAL :			**9774.90**		**8316.63**	
R.A.heat, leak gain& Safety factor (5%)			488.75		415.83	
GRAND TOTAL :			**10263.65**		**8732.46**	
TONS = {(W)/3500} :			**2.93**		**2.49**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.78		0.65	
INDICATED ADP :			10.00		8	
SELECTED ADP :			**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			11.44		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**30**		**16**	
Safety factor (5%)			2		2	
TOTAL DEHUMIDIFIED AIR:			**32**		**17**	

4.6.6 Cooling load calculation of Professors room



Length of the room = 3.57 m

Width of the room = 6.87 m

Height of the room = 3.40 m

Area of glass (W_1) = $1.5 \times 1.8 = 2.7 \text{ m}^2$

Area of the door (D_3) = $1.0 \times 2.7 = 2.7 \text{ m}^2$

Outside wall area (SE) = $3.57 \times 3.4 - 2.7 = 9.44 \text{m}^2$

Partition wall areas (NE, SW, NW) = $6.87 \times 3.4 + 6.87 \times 3.4 + (3.57 \times 3.4 - 2.7) = 56.15 \text{ m}^2$

Now the amount of infiltrated air through windows and walls is

$$= \frac{3.57 \times 6.87 \times 3.4 \times 1}{60} = 1.4 \text{ m}^3\text{/min}$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02 \times 24.53 = 0.5 \text{m}^3\text{/min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45 W/person

Lighting heat gain for office = 12 W/m^2

The details of cooling load calculations of the Professors room are given in Table 4.9

Table 4.9 Cooling load sheet of the Professors Room

	:		Area	:	NIT ROURKELA
Job No.	:	6	**City**	:	**Rourkela / Odisha**
Project	:	**TIIR BUILDING COOLING LOAD**	**Month**	:	**May for Summer and July for Monsson**
Space	:	**PROFESSORS ROOM**	**Time**		

				Summer				Monsoon			
Length (m)	=	3.57	**CONDITION**	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width (m)	=	6.87	**Outside**	43	32	46	0.0248	36	33	84	0.03122
Height (m)	=	3.40	**Inside**	23	16	50	0.00866	23	16	50	0.00866
Area (m^2)	=	25	**Difference**	20			0.0161	13			0.0226
Volume (m^3)	=	83									
BPF	=	0.12	No of Air Changes / Hr.	=	1.00			**filtrated Air(m3/mi**			**1.4**

			SUMMER		**Monsoon**	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	2.7	0.14	372	141	360	136
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	9.4	1.07	26	263.76	18	179.47
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	2.7	5.60	20	302.40	13	196.56
Partition 1	56	1.86	15	1567	8	835.5
Ceiling	25	2.82	15	1,037.45	8	553.30
Floor	25	4.50	2.5	276	2.5	275.9
HEAT GAIN DUE TO INFILTRATION						
Outside Air CFM	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.39	1	20.44	20	568.15	13	369.30
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	7	70		490		490
Lights(W/m2)	12	25		294		294
Motor (W)				0		0
Equipment (W)	250.0			250		250
		ROOM SENSIBLE HEAT SUBTOTAL :	**5189.28**		**3580.31**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	311.36		214.82	
		ROOM SENSIBLE HEAT (R.S.H.) :	**5500.64**		**3795.12**	
ROOM LATENT HEAT CALCULATIONS:						
Outside Air CFM	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
1.39	1	50000	0.01611	1119.48	0.0226	1567.70
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	7	45		315		315
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	71.72		94.13	
		ROOM LATENT HEAT (R.L.H.) :	**1506.21**		**1976.83**	
		ROOM TOTAL HEAT (R.T.H.) :	**7006.85**		**5771.95**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
0.5	0.88	20.44	20	176.46	13	114.70
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
0.5	0.88	50000	0.0161	347.70	0.0226	486.91
		SUBTOTAL :	**7531.01**		**6373.56**	
		R.A.heat, leak gain& Safety factor (5%)	376.55		318.68	
		GRAND TOTAL :	**7907.56**		**6692.24**	
		TONS = {(W)/3500} :	**2.26**		**1.91**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.79		0.66	
		INDICATED ADP :	10.00		8	
		SELECTED ADP :	**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	11.44		15.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**24**		**12**	
		Safety factor (5%)	1		1	
		TOTAL DEHUMIDIFIED AIR:	**25**		**14**	

4.6.7 Cooling load calculation of 120 Seated Lecture Room 2

Length of the room = 14.17 m

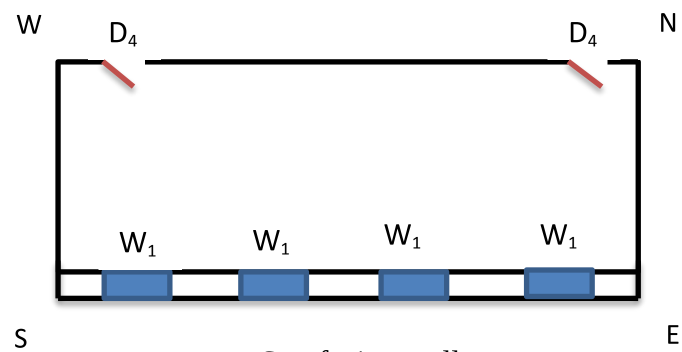
Width of the room = 8.67 m

Height of the room = 3.40 m

Area of glass (W_1) = $1.5\times1.8 = 2.7$ m^2

Area of the door (D_4) = $1.5\times2.7 = 4.05$ m^2

Total sun facing glass area = $2.7\times4 = 10.8$ m^2



Sun facing wall

Outside wall area (SE) = $14.17\times3.4-4\times2.7=37.38\,\text{m}^2$

Partition wall areas (NE, NW, SW) = $8.67\times3.4+8.67\times3.4+(14.17\times3.4-2\times4.05)$ = 99.034 m^2

Now the amount of infiltrated air through windows and walls is

$$=\frac{14.17\times8.67\times3.4\times1}{60}=6.97\ \text{m}^3/\text{min}$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02\times123=2.5\,\text{m}^3/\text{min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 15W/m^2

The details of cooling load calculations of the 120 seated lecture room are given in Table 4.10

Table 4.10 Cooling load sheet of 120 Seated Lecture Room 2

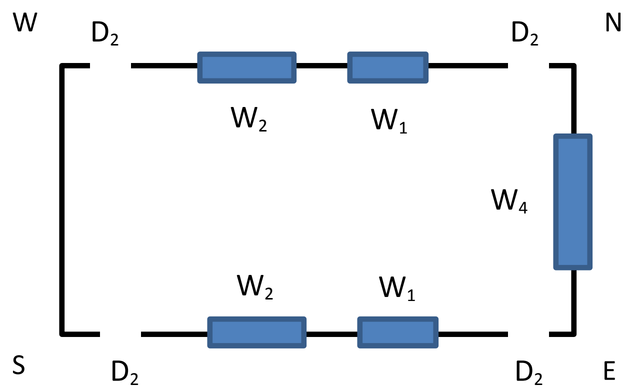
	:		Area	:	NIT ROURKELA
Job No.	:	7	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	120 SEAT LECTURE ROOM 2	Time		

				Summer				Monsoon			
Length (m)	=	14.17									
Width (m)	=	8.67	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height (m)	=	3.40	Outside	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	123	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	418	Difference	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.	=	1.00			filtrated Air(m3/mi			7

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	10.8	0.14	372	563	360	544
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	37.4	1.07	26	1,045.00	18	711.02
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	10.8	5.60	20	1,209.60	13	786.24
Partition 1	107	1.86	15	2991	8	1595.1
Ceiling	123	2.82	15	5,196.72	8	2,771.58
Floor	123	4.50	2.5	1382	2.5	1382.1
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
7	1	20.44	20	2845.95	13	1849.87
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	121	70		8470		8470
Lights(W/m2)	15	123		1843		1843
Motor (KW)				0		0
Equipment (KW)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**25545.89**		**19952.52**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	1532.75		1197.15	
		ROOM SENSIBLE HEAT (R.S.H.) :	**27078.65**		**21149.67**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
7	1	50000	0.01611	5607.67	0.0226	7852.82
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	121	45		5445		5445
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	552.63		664.89	
		ROOM LATENT HEAT (R.L.H.) :	**11605.30**		**13962.71**	
		ROOM TOTAL HEAT (R.T.H.) :	**38683.95**		**35112.38**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.5	0.88	20.44	20	883.92	13	574.55
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
2.5	0.88	50000	0.0161	1741.68	0.0226	2438.99
		SUBTOTAL :	**41309.54**		**38125.92**	
		R.A.heat, leak gain& Safety factor (5%)	2065.48		1906.30	
		GRAND TOTAL :	**43375.02**		**40032.22**	
		TONS = {(W)/3500} :	**12.39**		**11.44**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.70		0.60	
		INDICATED ADP :	8.00		7	
		SELECTED ADP :	**9.00**		**7.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	12.32		16.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**108**		**65**	
		Safety factor (5%)	5		6	
		TOTAL DEHUMIDIFIED AIR:	**113**		**71**	

4.6.8 Cooling load calculation of Office Room



Length of the room = 12.27m

Width of the room = 6.97 m

Height of the room = 3.40 m

Sun facing wall

Area of glass (W_1) = $1.5 \times 1.8 = 2.7\ \text{m}^2$

Area of glass (W_2) = $2.4 \times 1.8 = 4.32\ \text{m}^2$

Area of glass (W_4) = $3.6 \times 1.8 = 6.48\ \text{m}^2$

Area of the door (D_2) = $1.2 \times 2.7 = 3.24\ \text{m}^2$

Outside wall area (SW) = $6.97 \times 3.4 = 23.7\,\text{m}^2$

Partition wall areas (NE, NW, SE) =

$$(6.97 \times 3.4 - 6.48) + [(12.27 \times 3.4) - (2.7 + 4.32 + 3.24 \times 2)] \times 2 = 73.65\ \text{m}^2$$

Now the amount of infiltrated air through windows and walls is

$$= \frac{12.27 \times 6.97 \times 3.4 \times 1}{60} = 4.85\ \text{m}^3/\text{min}$$

Ventilation requirement/m^2 = $0.02\ \text{m}^3/\text{min}$

Total ventilation required = $0.02 \times 85.52 = 1.71\,\text{m}^3/\text{min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 12 W/m^2

The details of cooling load calculations of the Office Room are given in Table 4.11

Table 4.11 Cooling load sheet of Office Room

	:		Area	:	NIT ROURKELA
Job No.	:	8	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	OFFICE ROOM	Time		

				Summer				Monsoon			
Length (m)	=	12.27	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width (m)	=	6.97									
Height (m)	=	3.40	Outside	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	86	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	291	Difference	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.	=	1.00			filtrated Air(m3/mi			4.85

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		2.16	24	-	17	-
Wall (N-E)		2.16	31	-	24	-
Wall (E)		2.16	34	-	27	-
Wall (S-E)		2.16	25	-	18	-
Wall (S)		2.16	23	-	16	-
Wall (S-W)	23.7	2.16	25	1,284.92	18	926.58
Wall (W)		2.16	26	0	19	0
Wall (W-N)		2.16	26	0	19	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	20.5	5.60	20	2,298.24	13	1,493.86
Partition 1	74	1.86	15	2053	8	1095.2
Ceiling	86	2.82	15	3,617.58	8	1,929.37
Floor	86	4.50	2.5	962	2.5	962.1
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air(m3/min)	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
4.85	1	20.44	20	1981.14	13	1287.74
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	15	70		1050		1050
Lights(W/m2)	12	86		1026		1026
Motor (W)				0		0
Equipment (W)	1350.0			1350		1350
		ROOM SENSIBLE HEAT SUBTOTAL :	**15623.70**		**11121.10**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	937.42		667.27	
		ROOM SENSIBLE HEAT (R.S.H.) :	**16561.13**		**11788.37**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air(m3/min)	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
4.85	1	50000	0.01611	3903.65	0.0226	5466.56
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	15	45		675		675
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	228.93		307.08	
		ROOM LATENT HEAT (R.L.H.) :	**4807.58**		**6448.64**	
		ROOM TOTAL HEAT (R.T.H.) :	**21368.70**		**18237.00**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.7	0.88	20.44	20	615.16	13	399.86
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.7	0.88	50000	0.0161	1212.12	0.0226	1697.41
SUBTOTAL :			**23195.98**		**20334.27**	
R.A.heat, leak gain& Safety factor (5%)			1159.80		1016.71	
GRAND TOTAL :			**24355.78**		**21350.99**	
TONS = {(W)/3500} :			**6.96**		**6.10**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.78		0.65	
INDICATED ADP :			9.00		8	
SELECTED ADP :			**9.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			12.32		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**66**		**38**	
Safety factor (5%)			3		4	
TOTAL DEHUMIDIFIED AIR:			**69**		**42**	

4.6.9 Cooling load calculation of Meeting Room

Length of the room = 12.27m

Width of the room = 6.97 m

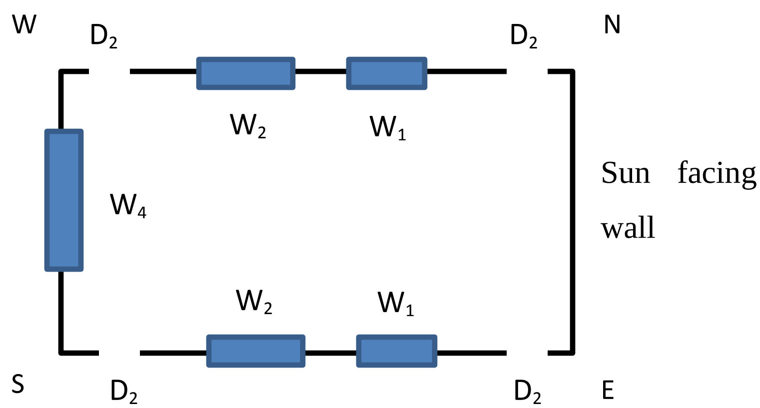
Height of the room = 3.40 m

Area of glass (W_1) $= 1.5\times1.8 = 2.7\ m^2$

Area of glass (W_2) $= 2.4\times1.8 = 4.32\ m^2$

Area of glass (W_4) $= 3.6\times1.8 = 6.48\ m^2$

Area of the door (D_2) $= 1.2\times2.7 = 3.24\ m^2$



Outside wall area (NE) $= 6.97\times3.4 = 23.7\,m^2$

Partition wall areas (SW, NW, SE) =

$$(6.97\times3.4-6.48)+[(12.27\times3.4)-(2.7+4.32+3.24\times2)]\times2 = 73.65\ m^2$$

Now the amount of infiltrated air through windows and walls is

$$=\frac{12.27\times6.97\times3.4\times1}{60} = 4.85\ m^3/min$$

Ventilation requirement/m^2 $= 0.02\ m^3/min$

Total ventilation required $= 0.02\times85.52 = 1.71\,m^3/min$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45 W/person

Lighting heat gain for office = 14 W/m^2

The details of cooling load calculations of the Meeting Room are given in Table 4.12

Table 4.12 Cooling load sheet of Meeting Room

	:		Area	:	NIT ROURKELA
Job No.	:	9	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	MEETING ROOM	Time		

				Summer				Monsoon			
Length (m)	=	12.27									
Width (m)	=	6.97	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height (m)	=	3.40	Outside	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	86	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	291	Difference	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.	= 1.00				filtrated Air(m3/mi			4.85

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		2.16	24	-	17	-
Wall (N-E)	23.7	2.16	31	1,592.07	24	1,233.73
Wall (E)		2.16	34	-	27	-
Wall (S-E)		2.16	25	-	18	-
Wall (S)		2.16	23	-	16	-
Wall (S-W)		2.16	25	-	18	-
Wall (W)		2.16	26	0	19	0
Wall (W-N)		2.16	26	0	19	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	20.5	5.60	20	2,298.24	13	1,493.86
Partition 1	74	1.86	15	2053	8	1095.2
Ceiling	86	2.82	15	3,617.58	8	1,929.37
Floor	86	4.50	2.5	962	2.5	962.1
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air(m3/min)	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
4.85	1	20.44	20	1981.14	13	1287.74
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	15	70		1050		1050
Lights(W/m2)	14	86		1197		1197
Motor (W)				0		0
Equipment (W)	270.0			270		270
		ROOM SENSIBLE HEAT SUBTOTAL :	**15021.90**		**10519.30**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	901.31		631.16	
		ROOM SENSIBLE HEAT (R.S.H.) :	**15923.21**		**11150.45**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air(m3/min)	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
4.85	1	50000	0.01611	3903.65	0.0226	5466.56
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	15	45		675		675
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	228.93		307.08	
		ROOM LATENT HEAT (R.L.H.) :	**4807.58**		**6448.64**	
		ROOM TOTAL HEAT (R.T.H.) :	**20730.79**		**17599.09**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.7	0.88	20.44	20	615.16	13	399.86
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.7	0.88	50000	0.0161	1212.12	0.0226	1697.41
SUBTOTAL :			**22558.07**		**19696.36**	
R.A.heat, leak gain& Safety factor (5%)			1127.90		984.82	
GRAND TOTAL :			**23685.97**		**20681.18**	
TONS = {(W)/3500} :			**6.77**		**5.91**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.77		0.63	
INDICATED ADP :			9.50		7	
SELECTED ADP :			**9.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			12.32		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**63**		**36**	
Safety factor (5%)			3		4	
TOTAL DEHUMIDIFIED AIR:			**66**		**40**	

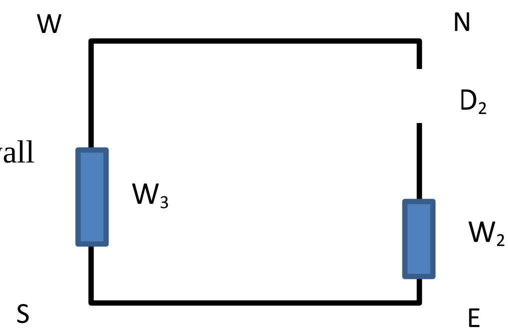
4.6.10 Cooling load calculation of Library

Length of the room = 6.97 m

Width of the room = 6.47 m

Height of the room = 3.32 m

Sun facing wall



Area of glass (W_2) = $2.4 \times 1.8 = 4.32$ m^2

Area of glass (W_3) = $3.0 \times 1.8 = 5.40$ m^2

Area of the door (D_2) = $1.2 \times 2.7 = 3.24$ m^2

Outside wall area (SW) = $6.47 \times 3.32 - 5.4 = 16.08\,\text{m}^2$

Partition wall areas (NE, NW, SE) = $(6.47 \times 3.32 - 4.32 - 3.24) + (6.97 \times 3.32) \times 2 = 60.2$ m^2

Now the amount of infiltrated air through windows and walls is

$$= \frac{6.47 \times 6.97 \times 3.32 \times 1}{60} = 2.5 \text{ m}^3\text{/min}$$

Ventilation requirement/m^2 = 0.04 m^3/min

Total ventilation required = $0.04 \times 45.1 = 1.8\,\text{m}^3$/min

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 13W/m^2

The details of cooling load calculations of the Library are given in Table 4.13

Table 4.13 Cooling load sheet of Library

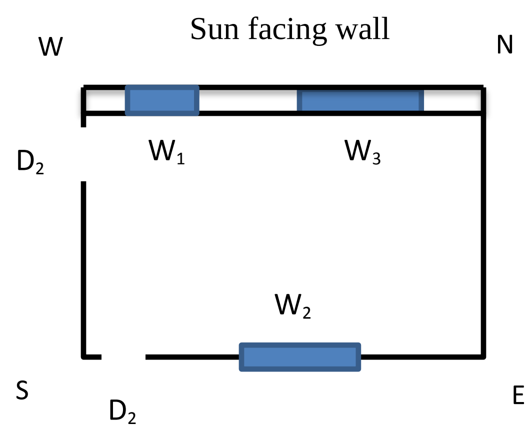
	:		Area	:	NIT ROURKELA
Job No.	:	10	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	LIBRARY	Time		

				Summer				Monsoon			
Length (m)	=	6.97	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width (m)	=	6.47									
Height (m)	=	3.32	Outside	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	45	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	150	Difference	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.	=	1.00			filtrated Air(m3/mi			2.50

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)	5.4	0.52	372	1045	360	1010
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		2.16	24	-	17	-
Wall (N-E)		2.16	31	-	24	-
Wall (E)		2.16	34	-	27	-
Wall (S-E)		2.16	25	-	18	-
Wall (S)		2.16	23	-	16	-
Wall (S-W)	16.1	2.16	25	872.88	18	629.45
Wall (W)		2.16	26	0	19	0
Wall (W-N)		2.16	26	0	19	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	9.7	5.60	20	1,088.64	13	707.62
Partition 1	60	1.86	15	1680	8	895.8
Ceiling	45	2.82	15	1,907.56	8	1,017.36
Floor	45	4.50	2.5	507	2.5	507.3
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air(m3/min)	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.50	1	20.44	20	1020.08	13	663.05
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	15	70		1050		1050
Lights(W/m2)	13	45		586		586
Motor (W)				0		0
Equipment (W)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**9757.57**		**7066.65**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	585.45		424.00	
		ROOM SENSIBLE HEAT (R.S.H.) :	**10343.02**		**7490.65**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air(m3/min)	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
2.50	1	50000	0.01611	2009.97	0.0226	2814.71
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	15	45		675		675
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	134.25		174.49	
		ROOM LATENT HEAT (R.L.H.) :	**2819.22**		**3664.19**	
		ROOM TOTAL HEAT (R.T.H.) :	**13162.24**		**11154.84**	

O U T S I D E A I R H E A T :						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.8	0.88	20.44	20	647.54	13	420.90
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.8	0.88	50000	0.0161	1275.91	0.0226	1786.75
		SUBTOTAL :	**15085.69**		**13362.49**	
		R.A.heat, leak gain& Safety factor (5%)	754.28		668.12	
		GRAND TOTAL :	**15839.97**		**14030.62**	
		TONS = {(W)/3500} :	**4.53**		**4.01**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.79		0.67	
		INDICATED ADP :	9.40		8	
		SELECTED ADP :	**9.00**		**8.00**	
D E H U M I D I F I E D A I R Q U A N T I T Y :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	12.32		15.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**41**		**24**	
		Safety factor (5%)	2		2	
		TOTAL DEHUMIDIFIED AIR:	**43**		**27**	

4.6.11 Cooling load calculation of Dining Room



Length of the room = 9.67 m

Width of the room = 6.97 m

Height of the room = 3.32 m

Area of glass (W_1) = $1.5 \times 1.8 = 2.7$ m^2

Area of glass (W_2) = $2.4 \times 1.8 = 4.32$ m^2

Area of glass (W_3) = $3.0 \times 1.8 = 5.40$ m^2

Area of the door (D_2) = $1.2 \times 2.7 = 3.24$ m^2

Outside wall area (NW) = $9.67 \times 3.32 - 5.4 - 2.7 = 24$ m^2

Partition wall areas (NE, SE, SW) =

$(6.97 \times 3.32) + (9.67 \times 3.32 - 4.32 - 3.24) + (6.97 \times 3.32 - 3.24) = 67.6$ m^2

Now the amount of infiltrated air through windows and walls is

$$= \frac{9.67 \times 6.97 \times 3.32 \times 1}{60} = 3.73 \text{ m}^3/\text{min}$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02 \times 67.4 = 1.35$ m^3/min

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 10W/m^2

The details of cooling load calculations of the Dining Room are given in Table 4.14

Table 4.14 Cooling load sheet of Dining Room

	:		Area	:	NIT ROURKELA				
Job No.	:	11	City	:	Rourkela / Odisha				
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson				
Space	:	DINING ROOM	Time						

			Summer				Monsoon			
Length (m) = 9.67	CONDITION		DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width (m) = 6.97	Outside		43	32	46	0.0248	36	33	84	0.03122
Height (m) = 3.32	Inside		23	16	50	0.00866	23	16	50	0.00866
Area (m^2) = 67	Difference		20			0.0161	13			0.0226
Volume (m^3) = 224										
BPF = 0.12	No of Air Changes / Hr.	= 1.00					filtrated Air(m3/mi			3.73

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)	8.1	0.47	527	2006	521	1982
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)		1.07	26	-	18	-
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)	24	1.07	27	685	21	528
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	12.4	5.60	20	1,391.04	13	904.18
Partition 1	68	1.86	15	1886	8	1005.9
Ceiling	67	2.82	15	2,851.02	8	1,520.54
Floor	67	4.50	2.5	758	2.5	758.2
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
3.73	1	20.44	20	1524.60	13	990.99
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	20	70		1400		1400
Lights(W/m2)	10	67		674		674
Motor (KW)				0		0
Equipment (KW)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**13175.39**		**9763.02**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	790.52		585.78	
		ROOM SENSIBLE HEAT (R.S.H.) :	**13965.92**		**10348.80**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
3.73	1	50000	0.01611	3004.08	0.0226	4206.83
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	20	45		900		900
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	195.20		255.34	
		ROOM LATENT HEAT (R.L.H.) :	**4099.28**		**5362.17**	
		ROOM TOTAL HEAT (R.T.H.) :	**18065.20**		**15710.97**	

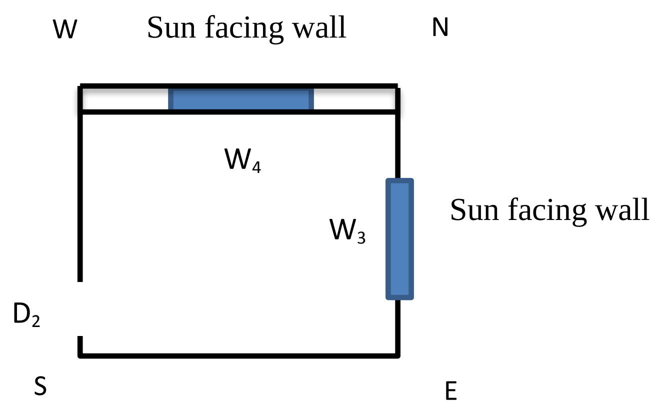
OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.35	0.88	20.44	20	484.93	13	315.21
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.35	0.88	50000	0.0161	955.51	0.0226	1338.08
SUBTOTAL :			**19505.65**		**17364.26**	
R.A.heat, leak gain& Safety factor (5%)			975.28		868.21	
GRAND TOTAL :			**20480.93**		**18232.47**	
TONS = {(W)/3500} :			**5.85**		**5.21**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.77		0.66	
INDICATED ADP :			9.60		7.6	
SELECTED ADP :			**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			11.44		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**60**		**34**	
Safety factor (5%)			3		3	
TOTAL DEHUMIDIFIED AIR:			**63**		**37**	

4.6.12 Cooling load calculation of Alumni Relation

Length of the room = 6.97 m

Width of the room = 6.97 m

Height of the room = 3.32 m



Area of glass (W_4) = $3.6 \times 1.8 = 6.48\ \text{m}^2$

Area of glass (W_3) = $3.0 \times 1.8 = 5.40\ \text{m}^2$

Area of the door (D_2) = $1.2 \times 2.7 = 3.24\ \text{m}^2$

Outside wall area (NW) = $6.87 \times 3.32 - 6.48 = 16.66\ \text{m}^2$

Outside wall area (NE) = $6.87 \times 3.32 - 5.4 = 17.74\ \text{m}^2$

Partition wall areas (SE, SW) = $(6.97 \times 3.32) + (6.97 \times 3.32 - 3.24) = 43.04\ \text{m}^2$

Now the amount of infiltrated air through windows and walls is

$$= \frac{6.97 \times 6.97 \times 3.32 \times 1}{60} = 2.7\ \text{m}^3/\text{min}$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02 \times 48.6 = 0.97\,\text{m}^3/\text{min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 12W/m^2

The details of cooling load calculations of the Alumni Relation Room are given in Table 4.15

Table 4.15 Cooling load sheet of Alumni Relation Room

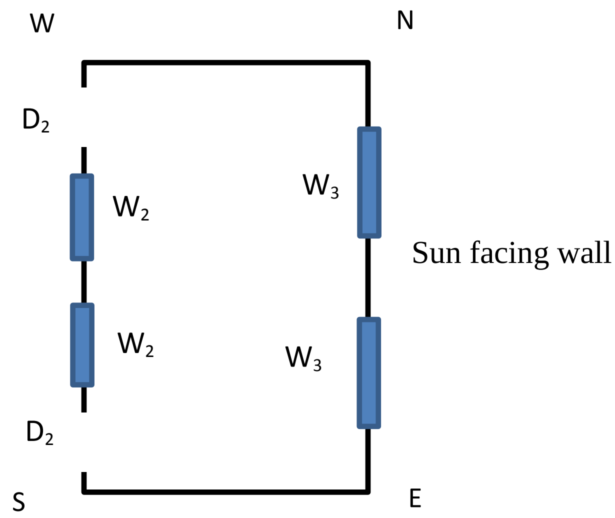
:		Area :	NIT ROURKELA
Job No. :	12	City :	Rourkela / Odisha
Project :	TIIR BUILDING COOLING LOAD	Month :	May for Summer and July for Monsson
Space :	ALUMNI RELATION	Time	

			Summer				Monsoon			
Length (m)	= 6.97									
Width (m)	= 6.97	**CONDITION**	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height (m)	= 3.32	**Outside**	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	= 49	**Inside**	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	= 161	**Difference**	20			0.0161	13			0.0226
BPF	= 0.12	No of Air Changes / Hr.	= 1.00				**filtrated Air(m3/mi**			**2.69**

			SUMMER		**Monsoon**	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)	5.4	0.13	527	370	521	365
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)	6.48	0.47	527	1604	521	1585
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		2.16	24	-	17	-
Wall (N-E)	17.7	2.16	31	1,191.70	24	923.47
Wall (E)		2.16	34	-	27	-
Wall (S-E)		2.16	25	-	18	-
Wall (S)		2.16	23	-	16	-
Wall (S-W)		2.16	25	-	18	-
Wall (W)		2.16	26	0	19	0
Wall (W-N)	16.66	1.07	27	481	21	374
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	11.9	5.60	20	1,330.56	13	864.86
Partition 1	43	1.86	15	1200	8	639.8
Ceiling	49	2.82	15	2,054.97	8	1,095.99
Floor	49	4.50	2.5	547	2.5	546.5
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air(m3/min)	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.69	1	20.44	20	1098.91	13	714.29
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	10	70		700		700
Lights(W/m2)	12	49		583		583
Motor (W)				0		0
Equipment (W)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**11160.96**		**8392.97**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	669.66		503.58	
		ROOM SENSIBLE HEAT (R.S.H.) :	**11830.62**		**8896.54**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air(m3/min)	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
2.69	1	50000	0.01611	2165.30	0.0226	3032.23
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	10	45		450		450
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	130.76		174.11	
		ROOM LATENT HEAT (R.L.H.) :	**2746.06**		**3656.34**	
		ROOM TOTAL HEAT (R.T.H.) :	**14576.68**		**12552.88**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.0	0.88	20.44	20	348.95	13	226.82
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.0	0.88	50000	0.0161	687.57	0.0226	962.86
		SUBTOTAL :	**15613.21**		**13742.56**	
		R.A.heat, leak gain& Safety factor (5%)	780.66		687.13	
		GRAND TOTAL :	**16393.87**		**14429.69**	
		TONS = {(W)/3500} :	**4.68**		**4.12**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.81		0.71	
		INDICATED ADP :	10.00		8	
		SELECTED ADP :	**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	11.44		15.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**51**		**29**	
		Safety factor (5%)	3		3	
		TOTAL DEHUMIDIFIED AIR:	**53**		**32**	

4.6.13 Cooling load calculation of Alumni Visitors Room



Length of the room = 6.97 m

Width of the room = 12.74 m

Height of the room = 3.32 m

Area of glass (W_2) = $2.4 \times 1.8 = 4.32\ \text{m}^2$

Area of glass (W_3) = $3.0 \times 1.8 = 5.40\ \text{m}^2$

Area of the door (D_2) = $1.2 \times 2.7 = 3.24\ \text{m}^2$

Outside wall area (NE) = $12.74 \times 3.32 - 5.4 \times 2 = 31.5\ \text{m}^2$

Partition wall areas (SE, SW, NW) =

$$(6.97 \times 3.32) \times 2 + (12.74 \times 3.32 - 3.24 \times 2 - 4.32 \times 2) = 50.32\ \text{m}^2$$

Now the amount of infiltrated air through windows and walls is

$$= \frac{6.97 \times 12.74 \times 3.32 \times 1}{60} = 4.91\ \text{m}^3/\text{min}$$

Ventilation requirement/m^2 = $0.02\ \text{m}^3/\text{min}$

Total ventilation required = $0.02 \times 88.8 = 1.8\,\text{m}^3/\text{min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for office = 14W/m^2

The details of cooling load calculations of the Alumni Visitors Room are given in Table 4.16

Table 4.16 Cooling load sheet of Alumni Visitors Room

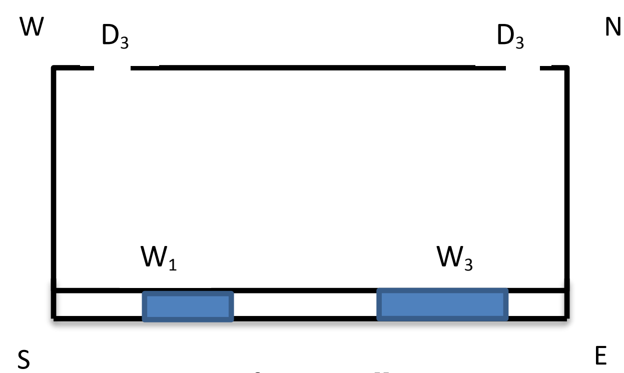
	:		Area	:	NIT ROURKELA
Job No.	:	13	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	ALUMNI VISITORS ROOM	Time		

				Summer				Monsoon			
Length (m)	=	6.97	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width (m)	=	12.74									
Height (m)	=	3.32	Outside	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	89	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	295	Difference	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.	=	1.00			filtrated Air(m3/mi			4.91

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)	10.8	0.13	527	740	521	731
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		2.16	24	-	17	-
Wall (N-E)	31.5	2.16	31	2,116.04	24	1,639.76
Wall (E)		2.16	34	-	27	-
Wall (S-E)		2.16	25	-	18	-
Wall (S)		2.16	23	-	16	-
Wall (S-W)		2.16	25	-	18	-
Wall (W)		2.16	26	0	19	0
Wall (W-N)		2.16	26	0	19	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	19.4	5.60	20	2,177.28	13	1,415.23
Partition 1	50.32	1.86	15	1404	8	748.8
Ceiling	89	2.82	15	3,756.15	8	2,003.28
Floor	89	4.50	2.5	999	2.5	999.0
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air(m3/min)	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
4.91	1	20.44	20	2008.63	13	1305.61
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	15	70		1050		1050
Lights(W/m2)	14	89		1243		1243
Motor (W)				0		0
Equipment (W)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**15493.82**		**11135.58**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	929.63		668.13	
		ROOM SENSIBLE HEAT (R.S.H.) :	**16423.45**		**11803.72**	
R O O M L A T E N T H E A T C A L C U L A T I O N S :						
Infiltrated Air(m3/min)	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
4.91	1	50000	0.01611	3957.81	0.0226	5542.40
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	15	45		675		675
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	231.64		310.87	
		ROOM LATENT HEAT (R.L.H.) :	**4864.45**		**6528.27**	
		ROOM TOTAL HEAT (R.T.H.) :	**21287.90**		**18331.99**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.8	0.88	20.44	20	647.54	13	420.90
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.8	0.88	50000	0.0161	1275.91	0.0226	1786.75
SUBTOTAL :			**23211.35**		**20539.64**	
R.A.heat, leak gain& Safety factor (5%)			1160.57		1026.98	
GRAND TOTAL :			**24371.92**		**21566.63**	
TONS = {(W)/3500} :			**6.96**		**6.16**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.77		0.64	
INDICATED ADP :			9.60		7.5	
SELECTED ADP :			**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			11.44		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**70**		**38**	
Safety factor (5%)			4		4	
TOTAL DEHUMIDIFIED AIR:			**74**		**42**	

4.6.14 Cooling load calculation of Interview Room 1



Sun facing wall

Length of the room = 5.23 m

Width of the room = 6.97 m

Height of the room = 3.35 m

Area of glass (W_1) = $1.5 \times 1.8 = 2.70$ m^2

Area of glass (W_3) = $3.0 \times 1.8 = 5.40$ m^2

Area of the door (D_3) = $1.0 \times 2.7 = 2.7$ m^2

Outside wall area (SE) = $5.23 \times 3.35 - 5.4 - 2.7 = 9.4$ m^2

Partition wall areas (SE, SW, NW) =

$$(6.97 \times 3.35) \times 2 + (5.23 \times 3.35 - 2.7 \times 2) = 58.82 \text{ m}^2$$

Now the amount of infiltrated air through windows and walls is

$$= \frac{6.97 \times 5.23 \times 3.35 \times 1}{60} = 2.04 \text{ m}^3/\text{min}$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02 \times 36.45 = 0.73$ m^3/min

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for multipurpose room = 14W/m^2

The details of cooling load calculations of the Alumni Relation Room are given in Table 4.17

Table 4.17 Cooling load sheet of Interview Room 1

	:		Area	:	NIT ROURKELA	
Job No.	:	14	City	:	Rourkela / Odisha	
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson	
Space	:	INTERVIEW ROOM 1	Time			

				Summer				Monsoon			
Length (m)	=	5.23									
Width (m)	=	6.97	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height (m)	=	3.35	Outside	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	36	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	122	Difference	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.	=	1.00			filtrated Air(m3/mi			2.04

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	8.1	0.14	372	422	360	408
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	9.4	1.07	26	262.65	18	178.71
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	8.1	5.60	20	907.20	13	589.68
Partition 1	59	1.86	15	1641	8	875.2
Ceiling	36	2.82	15	1,541.97	8	822.38
Floor	36	2.82	0	0	0	0.0
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.04	1	20.44	20	832.03	13	540.82
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	7	70		490		490
Lights(W/m2)	14	36		510		510
Motor (KW)				0		0
Equipment (KW)				0		0
ROOM SENSIBLE HEAT SUBTOTAL :			**6607.39**		**4414.99**	
S. A. heat gain, leak loss & Safety Factor (6%) :			396.44		264.90	
ROOM SENSIBLE HEAT (R.S.H.) :			**7003.83**		**4679.88**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
2	1	50000	0.01611	1639.43	0.0226	2295.82
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	7	45		315		315
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
S. A. heat gain, leak loss & Safety Factor (5%) :			97.72		130.54	
ROOM LATENT HEAT (R.L.H.) :			**2052.15**		**2741.36**	
ROOM TOTAL HEAT (R.T.H.) :			**9055.98**		**7421.24**	

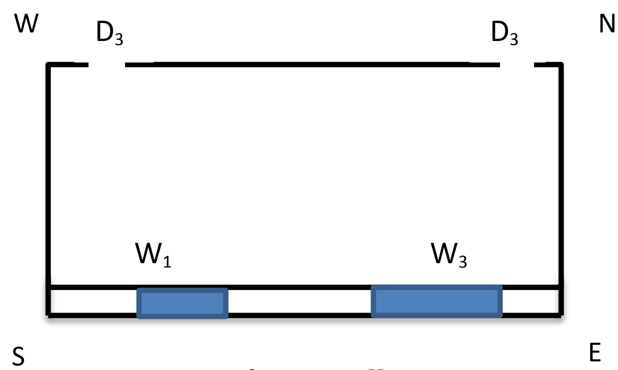
OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
0.73	0.88	20.44	20	262.28	13	170.48
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
0.73	0.88	50000	0.0161	516.79	0.0226	723.70
SUBTOTAL :			**9835.05**		**8315.42**	
R.A.heat, leak gain& Safety factor (5%)			491.75		415.77	
GRAND TOTAL :			**10326.80**		**8731.19**	
TONS = {(W)/3500} :			**2.95**		**2.49**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.77		0.63	
INDICATED ADP :			9.00		7.5	
SELECTED ADP :			**10.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY:						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			11.44		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**30**		**15**	
Safety factor (5%)			1		2	
TOTAL DEHUMIDIFIED AIR:			**31**		**17**	

4.6.15 Cooling load calculation of Interview Room 2

Length of the room = 9.07 m

Width of the room = 6.97 m

Height of the room = 3.35 m



Sun facing wall

Area of glass (W_1) = $1.5 \times 1.8 = 2.70 \text{ m}^2$

Area of glass (W_3) = $3.0 \times 1.8 = 5.40 \text{ m}^2$

Area of the door (D_3) = $1.0 \times 2.7 = 2.7 \text{ m}^2$

Outside wall area (SE) = $9.07 \times 3.35 - 5.4 - 2.7 = 22.28 \text{ m}^2$

Partition wall areas (SE, SW, NW) =

$$(6.97 \times 3.35) \times 2 + (9.07 \times 3.35 - 2.7 \times 2) = 71.68 \text{ m}^2$$

Now the amount of infiltrated air through windows and walls is

$$= \frac{6.97 \times 9.07 \times 3.35 \times 1}{60} = 3.53 \text{ m}^3\text{/min}$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02 \times 63.2 = 1.26 \text{ m}^3\text{/min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for multipurpose room = 14W/m^2

The details of cooling load calculations of the Interview Room 2 are given in Table 4.18

Table 4.18 Cooling load sheet of Interview Room 2

	:		Area	:	NIT ROURKELA
Job No.	:	15	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	INTERVIEW ROOM 2	Time		

				Summer				Monsoon			
			CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Length (m)	=	9.07	Outside	43	32	46	0.0248	36	33	84	0.03122
Width (m)	=	6.97	Inside	23	16	50	0.00866	23	16	50	0.00866
Height (m)	=	3.35	Difference	20			0.0161	13			0.0226
Area (m^2)	=	63									
Volume (m^3)	=	212									
BPF	=	0.12	No of Air Changes / Hr.	=	1.00			filtrated Air(m3/mi			3.53

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	8.1	0.14	372	422	360	408
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	22.3	1.07	26	622.53	18	423.57
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	8.1	5.60	20	907.20	13	589.68
Partition 1	72	1.86	15	2000	8	1066.6
Ceiling	63	2.82	15	2,674.12	8	1,426.20
Floor	63	2.82	0	0	0	0.0
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
3.53	1	20.44	20	1442.93	13	937.90
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	15	70		1050		1050
Lights(W/m2)	14	63		885		885
Motor (KW)				0		0
Equipment (KW)				0		0
		ROOM SENSIBLE HEAT SUBTOTAL :	**10003.82**		**6786.81**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	600.23		407.21	
		ROOM SENSIBLE HEAT (R.S.H.) :	**10604.05**		**7194.02**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
3.53	1	50000	0.01611	2843.15	0.0226	3981.46
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	15	45		675		675
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	175.91		232.82	
		ROOM LATENT HEAT (R.L.H.) :	**3694.05**		**4889.29**	
		ROOM TOTAL HEAT (R.T.H.) :	**14298.10**		**12083.31**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.26	0.88	20.44	20	454.85	13	295.65
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.26	0.88	50000	0.0161	896.23	0.0226	1255.05
		SUBTOTAL :	**15649.17**		**13634.01**	
		R.A.heat, leak gain& Safety factor (5%)	782.46		681.70	
		GRAND TOTAL :	**16431.63**		**14315.71**	
		TONS = {(W)/3500} :	**4.69**		**4.09**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.74		0.60	
		INDICATED ADP :	9.00		7	
		SELECTED ADP :	**9.00**		**7.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	12.32		16.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**42**		**22**	
		Safety factor (5%)	2		2	
		TOTAL DEHUMIDIFIED AIR:	**44**		**24**	

4.6.16 Cooling load calculation of Seminar Room

Length of the room = 12.53m

Width of the room = 6.97 m

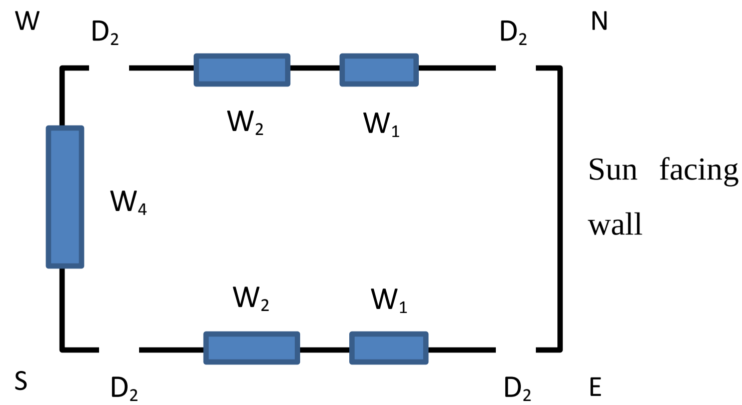
Height of the room = 3.35 m

Area of glass (W_1) = $1.5\times1.8 = 2.7\ m^2$

Area of glass (W_2) = $2.4\times1.8 = 4.32\ m^2$

Area of glass (W_4) = $3.6\times1.8 = 6.48\ m^2$

Area of the door (D_2) = $1.2\times2.7 = 3.24\ m^2$



Outside wall area (NE) = $6.97\times3.35 = 23.35\,m^2$

Partition wall areas (SW, NW, SE) =

$$(6.97\times3.35-6.48)+[(12.53\times3.35)-(2.7+4.32+3.24\times2)]\times2 = 73.82\ m^2$$

Now the amount of infiltrated air through windows and walls is

$$=\frac{12.27\times6.97\times3.35\times1}{60} = 4.88\ m^3/min$$

Ventilation requirement/m^2 = $0.02\ m^3/min$

Total ventilation required = $0.02\times87.33 = 1.74\,m^3/min$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45 W/person

Lighting heat gain for office = 14 W/m^2

The details of cooling load calculations of the Seminar Room are given in Table 4.19

Table 4.19 Cooling load sheet of Seminar Room

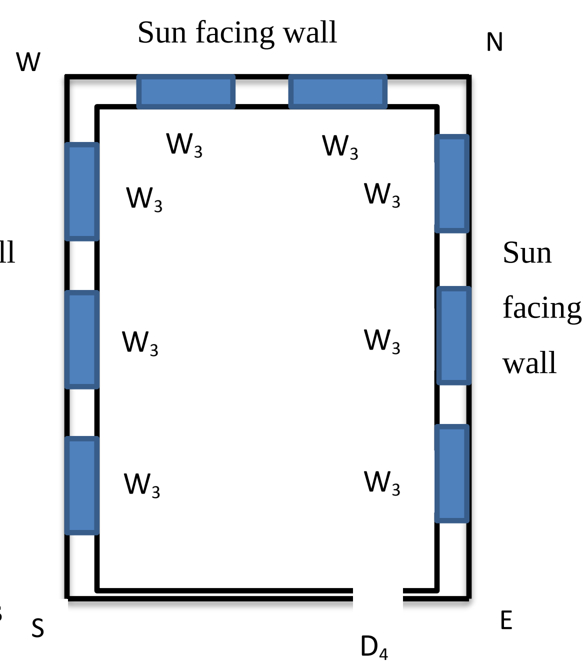
	:		Area	:	NIT ROURKELA	
Job No.	:	16	City	:	Rourkela / Odisha	
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson	
Space	:	SEMINAR ROOM	Time			

					Summer				Monsoon			
Length	(m)	=	12.53									
Width	(m)	=	6.97	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height	(m)	=	3.35	Outside	43	32	46	0.0248	36	33	84	0.03122
Area	(m^2)	=	87	Inside	23	16	50	0.00866	23	16	50	0.00866
Volume	(m^3)	=	293	Difference	20			0.0161	13			0.0226
BPF		=	0.12	No of Air Changes / Hr.		=	1.00			filtrated Air(m3/mi		4.88

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		2.16	24	-	17	-
Wall (N-E)	23.4	2.16	31	1,568.56	24	1,215.51
Wall (E)		2.16	34	-	27	-
Wall (S-E)		2.16	25	-	18	-
Wall (S)		2.16	23	-	16	-
Wall (S-W)		2.16	25	-	18	-
Wall (W)		2.16	26	0	19	0
Wall (W-N)		2.16	26	0	19	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	20.5	5.60	20	2,298.24	13	1,493.86
Partition 1	74	1.86	15	2060	8	1098.4
Ceiling	87	2.82	15	3,694.23	8	1,970.26
Floor	87	2.82	0	0	0	0.0
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air(m3/min)	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
4.88	1	20.44	20	1993.37	13	1295.69
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	30	70		2100		2100
Lights(W/m2)	14	87		1223		1223
Motor (W)				0		0
Equipment (W)	625.0			625		625
		ROOM SENSIBLE HEAT SUBTOTAL :	**15561.66**		**11021.43**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	933.70		661.29	
		ROOM SENSIBLE HEAT (R.S.H.) :	**16495.36**		**11682.72**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air(m3/min)	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
4.88	1	50000	0.01611	3927.74	0.0226	5500.30
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	30	45		1350		1350
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	263.89		342.52	
		ROOM LATENT HEAT (R.L.H.) :	**5541.63**		**7192.82**	
		ROOM TOTAL HEAT (R.T.H.) :	**22036.99**		**18875.53**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
1.7	0.88	20.44	20	615.16	13	399.86
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
1.7	0.88	50000	0.0161	1212.12	0.0226	1697.41
SUBTOTAL :			**23864.27**		**20972.80**	
R.A.heat, leak gain& Safety factor (5%)			1193.21		1048.64	
GRAND TOTAL :			**25057.48**		**22021.44**	
TONS = {(W)/3500} :			**7.16**		**6.29**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.75		0.62	
INDICATED ADP :			9.00		8	
SELECTED ADP :			**9.00**		**8.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			12.32		15.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**66**		**38**	
Safety factor (5%)			3		4	
TOTAL DEHUMIDIFIED AIR:			**69**		**42**	

4.6.17 Cooling load calculation of Central Design Office



Length of the room = 14.17m

Width of the room = 20.09 m

Height of the room = 3.32 m

Area of glass (W_3) = $3.0\times1.8 = 5.40\ \text{m}^2$

Area of the door (D_4) = $1.5\times2.7 = 4.05\ \text{m}^2$

Outside wall area (NE) = $20.09\times3.32-5.4\times3=50.5\,\text{m}^2$

Outside wall area (SW) = $20.09\times3.32-5.4\times3=50.5\,\text{m}^2$

Outside wall area (NW) = $14.17\times3.32-5.4\times2=36.24\,\text{m}^2$

Partition wall areas (SE) = $14.17\times3.32-4.05 = 43\ \text{m}^2$

Now the amount of infiltrated air through windows and walls is

$$=\frac{14.17\times20.09\times3.32\times1}{60}=15.75\ \text{m}^3/\text{min}$$

Ventilation requirement/m^2 = 0.02 m^3/min

Total ventilation required = $0.02\times284.7=5.69\,\text{m}^3/\text{min}$

Occupant heat gain for office: - SHG = 70W/person and LHG = 45 W/person

Lighting heat gain for office = 12 W/m^2

The details of cooling load calculations of the Central Design Office are given in Table 4.20

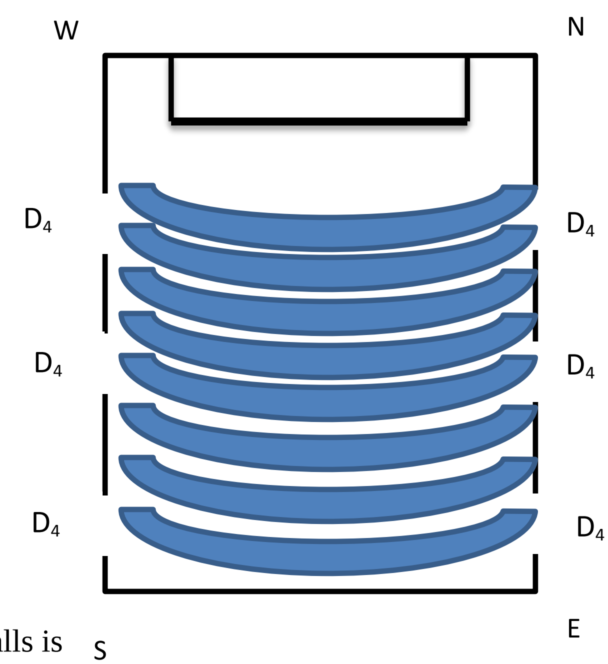
Table 4.20 Cooling load sheet of Central Design Office

	:		Area	:	NIT ROURKELA
Job No.	:	17	**City**	:	**Rourkela / Odisha**
Project	:	**TIIR BUILDING COOLING LOAD**	**Month**	:	**May for Summer and July for Monsson**
Space	:	**CENTRAL DESIGN OFFICE**	**Time**		

				Summer				Monsoon			
Length (m)	=	14.17	**CONDITION**	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width (m)	=	20.09	**Outside**	43	32	46	0.0248	36	33	84	0.03122
Height (m)	=	3.32	**Inside**	23	16	50	0.00866	23	16	50	0.00866
Area (m^2)	=	285	**Difference**	20			0.0161	13			0.0226
Volume (m^3)	=	945									
BPF	=	0.12	No of Air Changes / Hr.	= 1.50				**filtrated Air(m3/mi**			**23.63**

			SUMMER		**Monsoon**	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)	16.2	0.13	527	1109	521	1096
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)	16.2	0.52	372	3136	360	3029
Glass (W)		0.52	631	0	618	0
Glass (N-W)	10.8	0.47	527	2674	521	2642
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)	50.5	2.16	31	3,381.48	24	2,617.92
Wall (E)		1.07	28	-	21	-
Wall (S-E)		1.07	26	-	18	-
Wall (S)		1.07	22	-	13	-
Wall (S-W)	50.5	1.07	26	1,411.03	18	960.07
Wall (W)		1.07	28	0	21	0
Wall (W-N)	36.2	1.07	27	1034	21	797
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	43.2	5.60	20	4,838.40	13	3,144.96
Partition 1	43	1.86	15	1200	8	639.8
Ceiling	285	2.82	15	12,041.77	8	6,422.27
Floor	285	2.82	2.5	2007	2.5	2007.0
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
23.63	1	20.44	20	9659.15	13	6278.45
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	25	70		1750		1750
Lights(W/m2)	12	285		3416		3416
Motor (KW)				0		0
Equipment (KW)	3125.0			3125		3125
		ROOM SENSIBLE HEAT SUBTOTAL :	**50783.08**		**37926.01**	
		S. A. heat gain, leak loss & Safety Factor (6%) :	3046.98		2275.56	
		ROOM SENSIBLE HEAT (R.S.H.) :	**53830.06**		**40201.57**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
23.63	1	50000	0.01611	19032.39	0.0226	26652.44
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	25	45		1125		1125
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
		S. A. heat gain, leak loss & Safety Factor (5%) :	1007.87		1388.87	
		ROOM LATENT HEAT (R.L.H.) :	**21165.26**		**29166.31**	
		ROOM TOTAL HEAT (R.T.H.) :	**74995.32**		**69367.88**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
5.7	0.88	20.44	20	2048.20	13	1331.33
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
5.7	0.88	50000	0.0161	4035.78	0.0226	5651.60
SUBTOTAL :			**81079.31**		**76350.81**	
R.A.heat, leak gain& Safety factor (5%)			4053.97		3817.54	
GRAND TOTAL :			**85133.28**		**80168.35**	
TONS = {(W)/3500} :			**24.32**		**22.91**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.72		0.58	
INDICATED ADP :			10.00		7	
SELECTED ADP :			**10.00**		**7.00**	
DEHUMIDIFIED AIR QUANTITY :						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			11.44		16.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**230**		**123**	
Safety factor (5%)			12		12	
TOTAL DEHUMIDIFIED AIR:			**242**		**135**	



4.6.18 Cooling load calculation of Auditorium

Length of the Auditorium = 20 m

Width of the Auditorium = 25 m

Average height of the Auditorium = 3.32 m

Area of the door (D_1) = $2.0 \times 2.7 = 5.4$ m^2

Area of the door (D_5) = $0.9 \times 2.7 = 2.43$ m^2

Partition wall area (NE) = $185.85 - 3 \times 5.4 = 169.65$ m^2

Partition wall area (SW) = $185.85 - 3 \times 5.4 = 169.65$ m^2

Partition wall area (NW) = $9 \times 20 - 2 \times 2.43 = 175.14$ m^2

Partition wall area (SE) = $4.65 \times 20 = 93$ m^2

Now the amount of infiltrated air through windows and walls is

$$= \frac{20 \times 25 \times 7.55 \times 0.5}{60} = 34.955 \text{ m}^3/\text{min}$$

Ventilation requirement/m^2 = 0.05 m^3/min

Total ventilation required = $0.05 \times 500 = 25$ m^3/min

Occupant heat gain for Auditorium: - SHG = 65 W/person and LHG = 30 W/person

Lighting heat gain for office = 10 W/m^2

The details of cooling load calculations of the Auditorium are given in Table 4.21

Table 4.21 Cooling load sheet of Auditorium

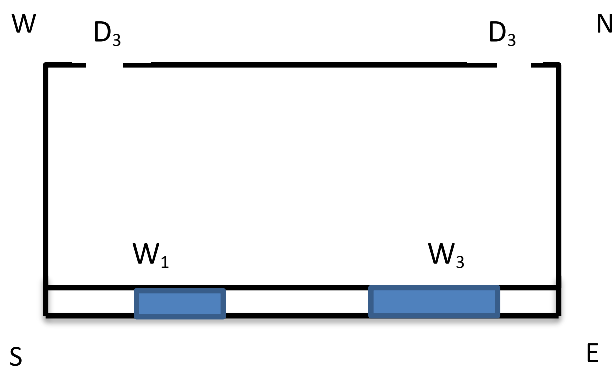
	:		Area	:	NIT ROURKELA
Job No.	:	18	**City**	:	**Rourkela / Odisha**
Project	:	**TIIR BUILDING COOLING LOAD CALCULATION**	**Month**	:	**May for Summer and July for Monsson**
Space	:	**AUDITORIUM**	**Time**		

				Summer				Monsoon			
Length (m)	=	20.00									
Width (m)	=	25.00	**CONDITION**	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height (m)	=	7.55	**Outside**	43	32	46	0.0248	36	33	84	0.03122
Area (m^2)	=	500	**Inside**	23	16	50	0.00866	23	16	50	0.00866
Volume (m^3)	=	3775	**Difference**	20			0.0161	13			0.0226
BPF	=	0.12	No of Air Changes / Hr.	= 0.50				**filtrated Air(m3/mi**			**31.5**

			SUMMER		**Monsoon**	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)		1.07	26	-	18	-
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass		5.60	20	-	13	-
Partition 1	607	1.86	15	16948	8	9038.7
Ceiling	500	2.82	15	21,150.00	8	11,280.00
Floor	500	2.82	2.5	3525	2.5	3525.0
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
31.5	1	20.44	20	12860.17	13	8359.11
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	400	65		26000		26000
Lights(W/m2)	10	500		5000		5000
Motor (KW)				0		0
Equipment (KW)	10000.0			10000		10000
ROOM SENSIBLE HEAT SUBTOTAL :			**95482.74**		**73202.82**	
S. A. heat gain, leak loss & Safety Factor (6%) :			5728.96		4392.17	
ROOM SENSIBLE HEAT (R.S.H.) :			**101211.71**		**77594.98**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
31.5	1	50000	0.01611	25339.69	0.0226	35485.00
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	400	30		12000		12000
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
S. A. heat gain, leak loss & Safety Factor (5%) :			1866.98		2374.25	
ROOM LATENT HEAT (R.L.H.) :			**39206.67**		**49859.25**	
ROOM TOTAL HEAT (R.T.H.) :			**140418.38**		**127454.23**	

OUTSIDE AIR HEAT:						
			OUTSIDE AIR SENSIBLE HEAT (OASH)			
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
25.0	0.88	20.44	20	8993.60	13	5845.84
			OUTSIDE AIR LATENT HEAT (OALH)			
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
25.0	0.88	50000	0.0161	17721.00	0.0226	24816.00
		SUBTOTAL :	**167132.98**		**158116.07**	
		R.A.heat, leak gain& Safety factor (5%)	8356.65		7905.80	
		GRAND TOTAL :	**175489.63**		**166021.88**	
		TONS = {(W)/3500} :	**50.14**		**47.43**	
		SENSIBLE HEAT FACTOR = (RSH/RTH) :	0.72		0.61	
		INDICATED ADP :	9.00		7	
		SELECTED ADP :	**9.00**		**7.00**	
DEHUMIDIFIED AIR QUANTITY :						
		Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :	12.32		16.00	
		DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :	**402**		**237**	
		Safety factor (5%)	20		24	
		TOTAL DEHUMIDIFIED AIR:	**422**		**261**	

4.6.19 Cooling load calculation of Library facilities



Sun facing wall

Length of the room = 9.07 m

Width of the room = 6.87 m

Height of the room = 3.35 m

Area of glass (W_1) = $1.5\times1.8 = 2.70$ m^2

Area of glass (W_3) = $3.0\times1.8 = 5.40$ m^2

Area of the door (D_3) = $1.0\times2.7 = 2.7$ m^2

Outside wall area (SE) = $9.07\times3.35-5.4-2.7=22.28$ m^2

Partition wall areas (SE, SW, NW) =

$$(6.87\times3.35)\times2+(9.07\times3.35-2.7\times2) = 71.01 \text{ m}^2$$

Now the amount of infiltrated air through windows and walls is

$$=\frac{6.87\times9.07\times3.35\times1}{60}=3.48 \text{ m}^3/\text{min}$$

Ventilation requirement/m^2 = 0.04 m^3/min

Total ventilation required = $0.04\times62.11=2.48$ m^3/min

Occupant heat gain for office: - SHG = 70W/person and LHG = 45W/person

Lighting heat gain for multipurpose room = 13W/m^2

The details of cooling load calculations of the Library facilities are given in Table 4.22

Table 4.22 Cooling load sheet of Library Facilities

	:		Area	:	NIT ROURKELA
Job No.	:	19	City	:	Rourkela / Odisha
Project	:	TIIR BUILDING COOLING LOAD	Month	:	May for Summer and July for Monsson
Space	:	LIBRARY FACILITIES	Time		

			Summer				Monsoon			
Length (m) =	9.07	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width (m) =	6.87	Outside	43	32	46	0.0248	36	33	84	0.03122
Height (m) =	3.35	Inside	23	16	50	0.00866	23	16	50	0.00866
Area (m^2) =	62	Difference	20			0.0161	13			0.0226
Volume (m^3) =	209									
BPF = 0.12		No of Air Changes / Hr.		= 1.00			filtrated Air(m3/mi			3.48

			SUMMER		Monsoon	
SOLAR HEAT GAIN FOR GLASS						
Item	Area (sq. m)	Factor	W/m²	W	W/m²	W
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)	8.1	0.14	372	422	360	408
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W)		0.47	527	0	521	0
SOLAR & TRANSMISSION HEAT GAIN FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall (N)		1.07	23	-	16	-
Wall (N-E)		1.07	27	-	21	-
Wall (E)		1.07	28	-	21	-
Wall (S-E)	22.3	1.07	26	622.53	18	423.57
Wall (S)		1.07	22	-	13	-
Wall (S-W)		1.07	26	-	18	-
Wall (W)		1.07	28	0	21	0
Wall (W-N)		1.07	27	0	21	0
Roof Sun		4.16	47	-	40	-
TRANSMISSION HEAT GAIN EXCEPT FOR WALLS & ROOF						
Item	Area (sq. m)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All Glass	8.1	5.60	20	907.20	13	589.68
Partition 1	71	1.86	15	1981	8	1056.5
Ceiling	62	2.82	15	2,635.75	8	1,405.73
Floor	62	2.82	0	0	0	0.0
HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
3.48	1	20.44	20	1422.23	13	924.45
INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	30	70		2100		2100
Lights(W/m2)	13	62		810		810
Motor (KW)				0		0
Equipment (KW)				0		0
ROOM SENSIBLE HEAT SUBTOTAL :			**10900.77**		**7717.77**	
S. A. heat gain, leak loss & Safety Factor (6%) :			654.05		463.07	
ROOM SENSIBLE HEAT (R.S.H.) :			**11554.81**		**8180.83**	
ROOM LATENT HEAT CALCULATIONS:						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
3.48	1	50000	0.01611	2802.35	0.0226	3924.34
ITEM		Factor	Diff kg/kg	W	Diff kg/kg	W
No. Of People	30	45		1350		1350
Steam				0		0
Appliances				0		0
Vapour Trans				0		0
S. A. heat gain, leak loss & Safety Factor (5%) :			207.62		263.72	
ROOM LATENT HEAT (R.L.H.) :			**4359.97**		**5538.06**	
ROOM TOTAL HEAT (R.T.H.) :			**15914.79**		**13718.89**	

OUTSIDE AIR HEAT:						
OUTSIDE AIR SENSIBLE HEAT (OASH)						
Outside Air	1 - BPF	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
2.49	0.88	20.44	20	896.64	13	582.82
OUTSIDE AIR LATENT HEAT (OALH)						
Outside Air	1 - BPF	Factor	Diff kg/kg	W	Diff kg/kg	W
2.49	0.88	50000	0.0161	1766.74	0.0226	2474.09
SUBTOTAL :			**18578.16**		**16775.80**	
R.A.heat, leak gain& Safety factor (5%)			928.91		838.79	
GRAND TOTAL :			**19507.07**		**17614.59**	
TONS = {(W)/3500} :			**5.57**		**5.03**	
SENSIBLE HEAT FACTOR = (RSH/RTH) :			0.73		0.60	
INDICATED ADP :			9.00		7	
SELECTED ADP :			**9.00**		**7.00**	
DEHUMIDIFIED AIR QUANTITY:						
Room Rise = (1 - By-pass Factor) * (Room Temp - ADP) :			12.32		16.00	
DEHUMIDIFIED AIR = RSH / (20.44 * Dehumid. Rise) :			**46**		**25**	
Safety factor (5%)			2		3	
TOTAL DEHUMIDIFIED AIR:			**48**		**28**	

CHAPTER 5

Result and Discussion

The maximum cooling loads, sensible heat ratios and total dehumidify air quantities of the sample building (TIIR building) calculated using cooling load temperature difference (CLTD) method. In TIIR building there are total 19 rooms of four floors where air conditioning is required including auditorium, lecture rooms, meeting rooms, library etc. Each one of them is treated as separate system. The cooling load details for all rooms are given in Table 5.1 at summer (month of May) and in Table 5.2 at monsoon (month of July).

Table 5.1 Total cooling loads, SHR and total dehumidify air quantities for TIIR building at summer.

Room Name	Area of Room (m^2)	Total load (Tons)	SHR	Total Dehumidify air quantities (m^3/min)
120 seat lecture room 1	122.85	12.39	0.70	113
Direct TIIR	24.53	2.11	0.78	21
Admin office	36.21	3.03	0.78	32
Placement office	20.40	1.99	0.80	22
IPR office	36.21	2.93	0.78	32
Professors room	24.53	2.26	0.79	25
120 seat lecture room 2	122.86	12.39	0.70	113
Office room	85.52	6.96	0.78	69
Meeting room	85.52	6.77	0.77	66
Library	45.00	4.53	0.79	43
Dining	67.40	5.85	0.77	63
Alumni relation room	48.58	4.68	0.81	53
Alumni visitors room	88.80	6.96	0.77	74
Interview room 1	36.45	2.95	0.77	31
Interview room 2	63.21	4.69	0.74	44
Seminar room	87.33	7.16	0.75	69
Central design office	284.68	24.69	0.72	247

Auditorium	500.00	50.12	0.72	422
Library facilities	62.31	5.57	0.73	48
Total	**1842.39**	**168.03**	**Avg = 0.76**	**1587**

Table 5.2 Total cooling loads, SHR and total dehumidify air quantities for TIIR building at monsoon.

Room Name	Area of Room (m^2)	Total load (Tons)	SHR	Total Dehumidify air quantities (m^3/min)
120 seat lecture room 1	122.85	11.44	0.60	71
Direct TIIR	24.53	1.95	0.68	14
Admin office	36.21	2.60	0.65	17
Placement office	20.40	1.67	0.67	12
IPR office	36.21	2.49	0.65	17
Professors room	24.53	1.91	0.66	14
120 seat lecture room 2	122.86	11.44	0.60	71
Office room	85.52	6.10	0.65	42
Meeting room	85.52	5.91	0.63	40
Library	45.00	4.01	0.67	27
Dining	67.40	5.21	0.66	37
Alumni relation room	48.58	4.12	0.71	32
Alumni visitors room	88.80	6.16	0.64	42
Interview room 1	36.45	2.49	0.63	17
Interview room 2	63.21	4.09	0.60	24
Seminar room	87.33	6.29	0.62	42
Central design office	284.68	23.17	0.58	138
Auditorium	500.00	47.43	0.61	261
Library facilities	62.31	5.03	0.60	28
Total	**1842.39**	**153.51**	**Avg = 0.637**	**946**

The maximum cooling loads, sensible heat ratios and total dehumidify air quantities of the sample building (TIIR building) calculated with help of CARRIER program used by Blue Star India Ltd. The cooling load detail for TIIR building by CARRIER program is given in Table 5.3 for summer and in Table 5.4 for monsoon.

Table 5.3 Total cooling loads, SHR and total dehumidify air quantities for TIIR building at summer by CARRIER program.

Room Name	Area of Room (m^2)	Total load (Tons)	SHR	Total Dehumidify air quantities (m^3/min)
120 seat lecture room 1	122.85	13.45	0.63	98
Direct TIIR	24.53	2.561	0.69	19
Admin office	36.21	3.53	0.75	33
Placement office	20.40	2.17	0.72	17
IPR office	36.21	3.21	0.72	25
Professors room	24.53	2.33	0.72	19
120 seat lecture room 2	122.86	13.45	0.63	98
Office room	85.52	7.33	0.72	57
Meeting room	85.52	7.28	0.71	56
Library	45.00	4.87	0.76	38
Dining	67.40	5.45	0.70	63
Alumni relation room	48.58	4.98	0.77	39
Alumni visitors room	88.80	7.68	0.71	64
Interview room 1	36.45	3.40	0.74	28
Interview room 2	63.21	5.59	0.71	44
Seminar room	87.33	8.02	0.70	58
Central design office	284.68	30.21	0.67	207
Auditorium	500.00	52.34	0.64	352
Library facilities	62.31	5.87	0.70	48
Total	**1842.39**	**183.72**	**Avg = 0.704737**	**1362**

Table 5.4 Total cooling loads, SHR and total dehumidify air quantities for TIIR building at monsoon by CARRIER program.

Room Name	Area of Room (m^2)	Total load (Tons)	SHR	Total Dehumidify air quantities (m^3/min)
120 seat lecture room 1	122.85	13.19	0.54	68
Direct TIIR	24.53	2.48	0.58	12
Admin office	36.21	3.28	0.62	21
Placement office	20.40	2.05	0.61	9
IPR office	36.21	3.04	0.59	15
Professors room	24.53	2.20	0.60	10
120 seat lecture room 2	122.86	13.19	0.54	68
Office room	85.52	6.97	0.58	34
Meeting room	85.52	6.97	0.58	37
Library	45.00	4.62	0.66	29
Dining	67.40	5.21	0.66	37
Alumni relation room	48.58	4.98	0.66	28
Alumni visitors room	88.80	7.40	0.58	34
Interview room 1	36.45	3.19	0.61	18
Interview room 2	63.21	5.37	0.59	29
Seminar room	87.33	7.78	0.58	36
Central design office	284.68	28.16	0.55	138
Auditorium	500.00	52.00	0.55	236
Library facilities	62.31	5.03	0.60	28
Total	**1842.39**	**177.11**	**Avg = 0.594**	**886**

The result shows that when using CLTD method, the total cooling load of TIIR building is 168.03 tons for summer and 153.53 tons for monsoon. The average sensible heat ratio of the TIIR building is 0.76 for summer and 0.637 for monsoon. It shows that the cooling load calculation is properly done with well accounted of latent heat came from the people and infiltration, especially in humid weather. The total dehumidifies air of TIIR building is 1587 m^3/min for summer and 946 m^3/min for monsoon.

According to CARRIER program the total cooling load of TIIR building is 183.72 tons for summer and 177.11 tons for monsoon. The total average SHR come from CARRIER program method is 0.70 for summer and 0.59 for monsoon. The total dehumidifies air of TIIR building is 1362 m^3/min for summer and 886 m^3/min for monsoon.

5.1 Variation of results

The variation of heat gain between results obtained from two different i.e. CLTD method and CARRIER program methods are shown in Fig-5.1. It shows that there are little different between two methods and result are satisfactory as ASHRAE standards.

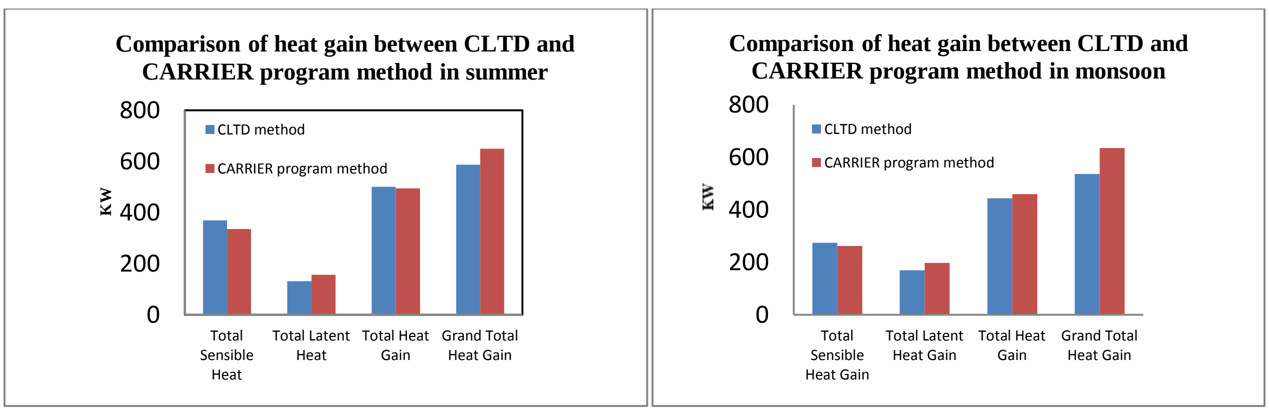


Fig:-5.1 Variation of heat gain between CLTD and CARRIER program method for summer and monsoon conditions.

CHAPTER 6

CONCLUSION

In this study, a multi-story building an integrated part of a research institution located in Rourkela was considered for calculating cooling loads. Cooling load temperature difference (CLTD) method was used to find the cooling load for summer (month of May) and monsoon (month of July).

Cooling load items such as, people, light, infiltration and ventilation can easily be putted to the MS-Excel program. The program can also be used to calculate cooling load due to walls and roofs.

- The results show that the total cooling load for the AC required rooms is 168.03 tons for summer (month of May) and for monsoon (month of July) total cooling load is 153.53 tons. The m^2/ton for the TIIR building is about 10.9 m^2/ton for summer and 12 m^2/ton for monsoon, which is approximately same, comparing with the standard value about 10 m^2/ton.
- The average sensible heat ratio of the building is 0.76 for summer and 0.637 for monsoon. It shows that the cooling load calculation is properly done with well accounted of latent heat came from the people and infiltration, especially in humid weather.
- The total dehumidify air of TIIR building is 1587 m^3/min for summer and 946 m^3/min for winter, for any office building the dehumidify air/m^2 area should have in the range of 0.75 to 0.91 cmm for summer and 0.5 to 65 cmm for monsoon and the dehumidify air/m^2 area of the TIIR building are 0.86 cmm for summer and 0.51cmm for monsoon.
- It is also seen that in this paper cooling requirement of summer is about 9 % more as compare to monsoon for climate condition of Rourkela.

These all factors show that the cooling load calculation of TIIR building is satisfactory.

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